Level 2 Certificate in Arboriculture Partial Portfolio

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§ 1

The Interaction of Soil Environments and Woody Plants

§1.1 – How Soil is Formed

§1.11 – Identify one of the three main rock constituents of soil.

One of the three most important components of soil is igneous rock. This is a rock which is formed directly from magma, which itself if primarily composed of silicon dioxide (SiO2). The ratio of silicon dioxide found therein, alongside the proportion of other elements, determines the type of magma and by extension the resultant solidified rock. For example, basaltic magma is by weight 45-55% silicon dioxide, with high amounts of iron, magnesium and calcium, and low amounts of potassium and sodium[1]. When this solidifies extrusivly it forms the darkly colour rock *basalt*.

§1.12 – Describe how rocks are broken down.

There are five means by which rocks - be it igneous, sedimentary or metamorphic – are broken down. The first of these is by water. Water can erode rock in a number of different ways. Being heavy it can simply hammer the rock until small particles break off and flow away. On the other hand, should water seep in through crevices, cracks or fault lines in the rock then the expansion or contraction of the liquid when subject to temperature changes can exert internal pressure which can subsequently break rock apart, or at least weaken it significantly leading to increased vulnerability from other forms or erosion.

Another manner in which rocks are broken down is by the aforementioned temperature changes. Since rock is chemically impure different constituents expand and contract at different rates. This difference between elements leads to internal pressures which can significantly weaken rock over long periods of time. Furthermore, heat – primarily from the sun – effects the top of the regolith more significantly than the relatively protected deeper areas, due to reduced light penetration. Therefore this results in a temperature gradient from the hotter surface downwards to the colder depths. Consequently, the higher layers see greater expansion from the heat than the lower layers, which results in *lateral* stresses which weaken rock.

Ice itself is another means by which rock is broken down. Ice and especially glaciers act like a big, solid abrasive agent which can rend the regolith apart – especially if the ice is moving and has seeped into the rock itself. Furthermore, the movement of ice can tear smaller particles apart as, once again, temperature gradients throughout the ice can lead to a fluid and changing environment.

The wind is also another way in which rocks can be broken down. On the one hand, there is the mere force of the wind hitting a rock which can, over time, lead to small portions breaking away. On the contrary, the wind can carry dust and other microscopic particles over long distances and this can culminate in one location where it gathers and acts as a powerful abrasive agent – a situation where rock can be battering rock which, although alone it exerts minute forces, together can result in a significant amount of energy being transferred – leading to fractures and subsequent failures of rock faces.

The last means by which rock can be broken down is via organic agents – such as flora or fauna. The former's roots can enter through cracks or crevices, and the mere growth of such can exert significant pressures which can break open rock or result in newer fault lines. The latter can provide mechanical energy, such as feet or paws walking on stone, or chemical energy, for example, the chemical reactions that result from the waste products of animals meeting with rock.

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[1] *"Volcanoes, Magma, and Volcanic Eruptions", Prof. Stephen A. Nelson, http://www.tulane.edu/~sanelson/Natural_Disasters/volcan&magma.htm (15-Sep-2015)*

§1.13 – Describe how a soil is formed.

There are four main ways in which soil is formed, of which three are also processes by which rock is broken down. That is to say that the majority of means by which rocks is broken down is also how it is transported from one place to another.

The first of these is via water by a method called alluvial transportation. For water to move it requires a great deal of energy since it is so heavy. Such energy naturally picks up loose detritus – the "loose fragments or grains that have been worn away from the rock"[2] – it consequently moving them from one place to another – as well as eroding them in the process. Once water slows, or the existing regolith absorbs it, it deposits the material onto the ground. Over extended periods of time, as different alluvial processes affect a given plain, the soil is built up and modified into complex forms. Marine operations are also a dominant form of alluvial processes due to the ability for sediment to travel long distances unimpeded.

Similar to the above, glaciers can move detritus via a process called moraine movement – "An accumulation of boulders, stones, or other debris carried and deposited by a glacier"[3]. This is to say that ice can move suspended detritus long distances as it moves over the earth, and once it thaws it drops the solids onto the ground which consequently forms new soils. This melting of ice may also contribute towards alluvial processes as the water continues to affect the rock.

In mountainous areas, the simple force of gravity can help soil formation in valleys. As rocks are weathered on mountains, they can fall away from the face and roll or drop downhill, whereupon they collect in depressions in the ground into a formation called scree. Should there be flowing rivers or wind in this area then they can be subsequently transported alluvially. The process of rock being moved by gravity itself is called colluvial movement.

Lastly, the wind is another factor in a process called aeolian transportation – which can be taken to mean something which is the result of the action of the wind. Although less powerful than alluvial transportation, wind can nonetheless pick up and carry loose or fine sediment and carry it from one place to another, whereupon it is deposited. An example of aeolian soil is sand dunes found at beaches – whereupon light sands are blown and deposited on an embankment.

§1.14 – Identify the role of organic matter in soil formation

One of the most important organic elements of soil – especially topsoil – is the jet coloured substance known as humus, which could be best described as decayed, oxidised or *humificated* organic matter. During the long formation process, of such complex molecules are broken down into simpler compounds which are more available to the plant's roots. In particular, complex amino acids and proteins, either from dead flora or fauna waste, are converted by microorganisms into nitrites (NO_2), which are then converted into plant-usable nitrates (NO_3)[4]. This process can continue, and these nitrates can be denitrified into nitrogen (N_2), which can then be utilised by different microorganisms to form the also plant usable ammonia (NH_3) – which then, to complete the cycle, can be converted into nitrites (NO_2). As we can see then, and from the diagram below, humus as a form of decayed organic matter, especially in the shape of something like *peat*, provides a valuable resource of the essential macronutrient nitrogen. Besides this humus does also contain some unique complex molecules, such as the humic and fulvic acids.

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[2] *"Detrius", The Free Dictionary, http://www.thefreedictionary.com/Detrius (15/11/2016)*

[3] *"Moraine", The Free Dictionary, http://www.thefreedictionary.com/moraine (15/11/2016)*

[4] *"The Nitrogen Cycle", RHS Botany for Gardeners, pp 146 (2013)*

On top of this, organic matter in the soil, such as humus, also contributes to an increase in the Cation Exchange Capacity (CEC) of said soil. The CEC determines, essentially, how well the soil can grab hold of and hold onto *positively charged ions*. Examples of such positively charged ions which are required by plants to thrive and which are held by negatively charged organic molecules are calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}), hydrogen (H^{+}) which plays a role in cation exchange[5], and importantly Ammonium (NH_4^{+}) which would otherwise be washed away.

Besides this organic matter also serves to insulate the soil, protecting roots in periods of extremely hot or cold weather, as well as promoting beneficial rhizobacteria in and around such. It also serves to retain moisture, and when mixed with loose soils it can prevent the washing away of vital nutrients. Regarding its importance in the ground formation, organic matter is critical in ensuring that soil contains a broad range of useful micro and macro nutrients. For example, a highly sandy soil with few nutrients would be far inferior to the same soil with a proportion of organic matter therein creating a micro ecosystem which aids in plants development.

§1.15 – Describe the properties of a minimum of three main constituents of soil

The three most important components of soil that we are most concerned with are *clay*, *silt*, and *sand*. These three types can broadly be described as follows:

> *Sandy* soils are typically composed of particulates of size 0.02mm – 0.2mm (per the British Standards Institute (BSI)). They can be course and gritty or smooth and fine.
>
> *Silty* soils are composed of particulates of size 0.002mm – 0.02mm (BSI). They feel silky to the touch, can be moderately worked, but are inherently unstable.
>
> *Clay* soils are composed of particulates of size less than 0.002mm (BSI). They are sticky and can easily be worked into a solid shape in hand.

§1.16 – Describe the effect on the soil of these main constituents

Sandy soils are well-draining, loose and "light" soils that are prone to nutrient leeching. They are quick to warm up, but also quick to freeze.[6] They have a small cumulative surface area and are thus have a poor CEC, however, they can easily be navigated by roots and also allow a large volume of oxygen to reach them. They can be improved with the introduction of organic colloid matter, such as humus.

On the other hand, silty soils are moderately well-draining and can hold a fair amount of water via capillary action. They are, however, prone to compacting in wet weather which can starve roots of oxygen[7]. They have a moderate surface area but cannot hold particularly many cations.

Lastly, clay is a poor draining "heavy" soil. Composed of inorganic colloids they are thus chemically active and consequently can hold an enormous volume of nutrient cations on accord of their extensive surface area. They are extremely prone to compaction when wet or waterlogged, and in dry weather can form a hard, impenetrable layer of material[8]. They have decent insulating properties and can hold heat well. Despite this should they freeze it can take a long time to thaw. They can impede the supply of

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[5] *"Soil Properties: Exchangeable Cations , Terragis,*

http://www.terragis.bees.unsw.edu.au/terraGIS_soil/sp_exchangeable_cations.html (15/11/2016)

[6] *"External Factors", RHS Botany for Gardeners, pp141-142 (2013)*

[7] *See 6.*

[8] *See 6.*

oxygen to the rhizosphere and can be difficult to navigate. They are not prone to nutrient leeching, and can rapidly expand or contract upon temperature extremes.

§1.17 – Identify why aggregates are important to soil structure

Aggregates are simply the way in which the ground's constituents are arranged macroscopically. The type of arrangement, and thus the aggregates, determines the overall *structure* of the soil and can impart properties upon it. For example, course block-like soils may be extremely permeable to roots, but may be prone to nutrient leeching, whilst plate-like soils may impair drainage if the internal structure is dissimilar – for example if a silty clay plate sits upon a compacted high-clay plates then the upper plate may become prone to waterlogging as the high-clay plate impairs drainage. Ultimately, however, the aggregates are important because they result in determinable, constant, and long-lasting properties and are consequently more chemically and physically stable than a completely structureless soil such as loamy sand. For example, the latter may be prone to nutrient leeching or drying out, while an aggregate would perhaps hold more water and cations.

§1.18 – Define the terms soil texture and structure

Soil texture could broadly be described as *how the soils feels*. More specifically, however, the texture of soil is determined by the size of the particulates found therein. These are the ranges that I have described in §1.15.

Soil structure describes, briefly, the general *layout* of the earth and the arrangement of its inorganic and organic constituents into aggregates. It also determines the pores and channels through which water and nutrients will flow.

One way to potentially describe both these terms is that soil texture is *what* something is, while soil structure is *how* it works in practice.

§1.19 – Identify a commonly found horizon of a soil profile

One of the most commonly found soil horizons, which occurs in most locations where there is floral growth, is the organic "O" horizon – or A0 horizon, which can be simply broken down into three stages described with the acronym LFH, or "Litter, fermented, humified".

Starting at the top most layer is the litter layer which is comprised of freshly, or near-freshly, fallen organic matter – such as leaves, flowers or seeds – which has yet to begin to decompose truly.

Sitting below this is the fermented layer which comprised of semi-decomposed organic matter. i.e. fermenting matter which is being broken down via aerobic microorganisms releasing simple sugars.

Beyond this is the humified layer. This layer can take many years to form and is characterised by high levels of decomposed organic material, a robust microbiological ecosystem, and the presence of humic and fulvic acids. However, a key fact is that it has yet to, or has only minimally, merged with the metallic element of the soil. Once the latter process begins, and organic and inorganic materials start to form aggregates, we enter the A1 transition layer.

§1.2 – Water Within the Soil

§1.21 – Describe how water moves within the soil

There are several different ways in which water moves within the soil. These include gravitational pressure, water table redistribution, electrostatic attraction and capillary action.

Gravitational pressure is merely the natural flow of water downwards and is responsible for the initial saturation of soil after a period of watering or precipitation. Water, being fluid, always flows to the lowest possible point achievable, and this can clearly be seen by simply using a funnel and pouring water in. Rather than sitting at the top of the apparatus the water flows downwards through the hole, seeking the lowest point.

Due to the asymmetrical nature of the water molecule (H_2O) positively and negatively charged ions can attract water and slowly and gently move water around the soil. When attracted by cations (positively charged ions), said molecules become *hydrated*. In this situation, the molecules are primarily bound *adhesively*.

In the case of water to water attraction they are linked *cohesively* and are primarily held together by surface tension. This latter phenomenon can be seen when, say, applying a foliar feed to plants – the water forms *cohesive* droplets on the surface of the leaves rather than spreading out in a thin film. The force that holds these droplets together in tight bundles is surface tension. In the soil, this is responsible for the movement of water via capillary action. This is the process whereby water can flow counter to the traditional forces at work, such as gravity, through small pores or tubes within the soil. This process is slow and gradual, but over time it can lead to complete saturation of the ground, especially if the water table is "feeding" the process.

The water table itself is the base level of water within the soil. For example, if the last foot of soil is fully saturated with water, then the water table is thus high. In well-draining soils, the water table may be lower than in poor draining soils since the water will flow through the particulates and pool in areas of greater resistance. This process is responsible for not only the movement of water but also the movement of nutrients, as well as erosion.

§1.22 – Define two of the eight terms applied to the different quantities of water found in the soil

One of the terms applied to the various volumes of water present in the soil is the *permanent wilting point*. This describes the point of wilting whereupon the plant can no longer recover. Regarding water quantity, it represents a form of extreme low-level moisture within the soil whereupon it cannot recover. This is perhaps seen most in drought-stricken areas where all available moisture has been utilised or removed from the ground.

The opposite of this volume is *field capacity* – whereupon the earth is holding the maximum possible moisture that it can hold in *natural* settings. If prevented from draining, and at full capacity, the soil would be described as *saturated*. Due to low surface tension, this situation is ideal for plants, although care should be taken to ensure that the fields are not waterlogged

§1.23 – Describe how pore size affects water retention in soil

Pore size could just explain how free-draining the soil is. Clay soils which have a tiny pore size hold a large volume of water, but it is held at such a high surface tension, due to the extensive surface area of the clay particulates, that most of it is unusable to plants. Small pores, in other words, have high water retention capabilities.

On the opposite end of the scale, sandy soils have a low surface tension, due to a small surface areas, and have thus large pores through which water is held weakly. Although this is beneficial for plants since the water is readily available to their roots, it can drain quickly leading to water deprivation. It thus has reduced water retention abilities.

In the middle of this is a trade-off between pore size and surface tension, as seen in loamy or silty soils. Here the pores are large enough to allow access to roots while also being small enough to have a high enough surface tension to hold moisture.

§1.3 – The Role of Macro & Micro-Nutrients in Woody Plants

§1.31 – Identify a macro and micronutrient found in soils

There are at least 18 elements that are vital to plant growth. Some are needed in large amounts and are termed macronutrients, while some are only necessary for minute quantities, and are termed micronutrients.

An example of a macro-nutrient is the imperative element *nitrogen* (N). By weight, plants are made up of nitrogen more than any other element. Only two nitrogen compounds are usable by plants: ammonium (NH_4) and nitrate (NO_3)[9]. Atmospheric nitrogen (N_2) is unusable unless fixated by microorganisms. An example of a micronutrient is *molybdenum* (Mo). Typically occurring and Molybdate (MoO_4) it is used as an essential nutrient in the enzymatic conversion of nitrates.[10]

§1.32 – Describe two ways in which soil type affects nutrient availability

One way in which soil type affects nutrient availability is its porosity. Well-draining soils, such as those constructed primarily from sand, which have a large pore size tend to be prone to nutrient leeching. This is the process by which nutrients are washed out of the soil due to poor retention capabilities. In sandy soils, the particulates do not tend to hold onto nutrient cations and therefore require repeated exposure to nutrient salts to ensure levels of micro and macro-nutrients remain adequate for plant growth.

On the other hand clay based soils are prone to holding onto large amounts of nutrients and have a high CEC which results in significant quantities of nutrients being available to plant roots.

§1.33 – Describe the role played in plant growth by two macro and one micronutrient

Since I have already discussed nitrogen (N) in §1.31 I would like to briefly describe the role played by the two other major macronutrients (per NPK fertilisers) – *phosphorous* (P) and *potassium* (K).

Phosphorous is typically absorbed by the roots in the form of *phosphates* (PO_4). Although it has many uses, one of the most important is that it is present in adenosine triphosphate (ATP) which is the primary means by which plants store and utilise energy[11]. Regarding plant growth, phosphorous is thus responsible for providing the fuel required for expansion and synthesis of new cellular components, proteins, carbohydrates, enzymes and nucleotides.

Another essential macronutrient is potassium, Available to plants mostly as free cations but also as chlorides (KCl), potassium in terms of growth is chiefly responsible for the production and movement of sugars and starches[12] as well as carbohydrates and proteins where it acts as an enzyme co-factor.

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[9] *"Forms of Nitrogen in the Soil ", Plant & Soil Sciences eLibrary,*

"http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447042&topicorder=2&maxto=8 (17/11/2016)

[10] *"Molybdenum In Plant Nutrition", Albion Minerals, http://www.albionplantnutrition.com/news/68-molybdenum-in-plant-nutrition (17/11/2016)*

[11] *"Adenosine Triphosphate – ATP", University of Bristol,*

http://www.bris.ac.uk/Depts/Chemistry/MOTM/atp/atp1.htm (17/11/2016)

[12] *"Hydroponics", Jeffrey Winterborne, pp 54 (2005)*

An example of a micronutrient is *copper* (Cu). Copper is a vital component of plastocyanin which is an enzyme which is acutely involved in photosynthesis[13], and thus is responsible for helping to provide the energy required for rapid growth.

§1.34 – Distinguish two symptoms of nutrient deficiency found in woody vegetation

One common symptom of nutrient deficiency found in plants is *chlorosis* – a discolouration of the leaves, typically to a yellow colour. The pattern of discolouration can provide vital clues to the specific nutrient that is deficient. Usually deficiency of *mobile* nutrients, such as nitrogen, magnesium and phosphorous, leads to chlorosis in older leaves first, which then tracks up the plant as the organism moves nutrients to areas of higher demand. Deficiency of *immobile* nutrients, such as calcium, sulphur and zinc tend to present with chlorosis in newer foliage first[14].

Another common symptom of nutrient deficiency is *stunted* or *slow growth*. This is commonly found when soil is deficient of the primary macronutrients: nitrogen, phosphorous and potassium. This is due to their importance in cellular growth and metabolism. Reduced yield also commonly comes hand in hand with this symptom.

§1.35 – Outline the nitrogen cycle

The nitrogen cycle chiefly begins with atmospheric nitrogen gas (N_2). This is fixated by microorganism into *ammonia* (NH_3). This is then converted into *nitrites* (NO_2), and then again into *nitrates* (NO_3)[15] – the existence of oxygen in both these compounds underlies the importance on allowing good aeration to the soil. In anaerobic, waterlogged, condition nitrates are denitrified back into atmospheric nitrogen. Plant primarily utilise nitrates in the above cycle. When the death of the organisms, whether flora or fauna, occurs bacterial processes putrefy the material in *ammonium* (NH_4) salts, which are also usable by plants. Nitrification can then turn ammonium back into nitrites, thereby re-entering the cycle. Ammonium can also be lost to the air.

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[13] *"Plastocyanin", R Nave, Georgia State University, http://hyperphysics.phy-astr.gsu.edu/hbase/Organic/Pc.html (17/11/2016)*

[14] *"Hydroponics", Jeffery Winterborne, pp 51-62 (2005)*

[15] *See 4*

§1.4 – The Role of Beneficial Organisms Found in Soil

§1.41 – Identify a minimum of three beneficial soil organisms

Three types of beneficial organisms are *earthworms*, *rhizobacteria* and certain species of non-parasitic fungi.

Worms are primarily involved in the breakdown of organic matter, thus increasing soil fertility. Their burrows also aid in the improvement of aeration within the soil, and their behaviour of turning over soil can mix organic and inorganic materials to create a highly rich and balanced environment for plant growth.

Rhizobacteria includes many organisms such as some species within the genus *Bacillus*. These form a symbiotic relationship with the plant's roots – whereby the plant provides energy, and the bacteria produce nutrients, such as by producing simple sugars or otherwise have an immune strengthening effect – for example by out competing parasitic organisms.

Lastly, some non-parasitic saprophytic fungi contribute to soil fertility by breaking down dead organic matter into plant-usable compounds.

§1.42 – Describe the two benefits that soil organisms can bring to the soil

Individual soil organisms, especially bacteria, which do not form mycorrhizal relationships with the roots of plants can help the soil immensely by fixating nitrogen from the atmosphere into plant-usable compounds. These bacteria are known as *diazotrophs*[16].

Another role that microorganisms, and microfauna, play in the development of fertile soil is through the breakdown of organic compounds into simpler elements. This can consequently benefit the soil by turning infertile, sterile or otherwise nutrient lacking soil into high-nutrient well draining soil that is indicative of healthy plant growth.

§1.41 – Describe two benefits that soil organisms can bring to the woody plant

One benefit of soil organisms that is of acute importance to woody plants in the development of symbiotic mutual mycorrhizal relationships with their roots. There are two primary types of such relationships: ectomycorrhizal and endomycorrhizal. Put simply, ectomycorrhiza form external relationships with the root tips, without penetrating the host, while endomycorrhiza penetrate the host. In both cases, it may be a case of alleloparasitism – a form of almost "controlled" parasitism whereby the host exudes organic fungitoxics from the roots to control the growth and spread of the organism. Whether actually parasitic or not, the host provides energy, in the form of carbohydrates[17], to the organism which then provides inorganic compounds for use by the host. In this way, then, woody plants can be benefited by the increase in the supply of inorganic compounds which might not otherwise be available.

Another advantage for woody plants comes from the improvement of soil structure. This develops not just from fungi, but also from bacteria and microfauna. Such creatures can cement aggregates together, which as previously mentioned can improve soil texture as well. For example, in a high-clay soil with poor drainage, microorganisms could form larger particulates which open pores and channels through which water can flow. Conversely, in high-sand soils microorganisms can contribute to the breakdown

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[16] *"Diazotroph", Biology-Online Dictonary, http://www.biology-online.org/dictionary/Diazotroph (18/11/2016)*

[17] *Harrison, Maria J. "Signalling in the arbuscular mycorrhizal symbiosis." Annu. Rev. Microbiol. 59 (2005): 19-42.*

of surface litter which subsequently is mixed by microfauna, such as earthworms, into the ground. This actions can improve soil fertility, drainage and CEC which ultimately serves to aid in the development of woody plants particularly in cases where roots may have difficulty penetrating, as in the case of compacted high-clay soils, or where drainage results in nutrient leeching, in the case of loose sandy soils.

§1.5 – Soil pH and the Ranges Found in Soil

§1.51 – Define the term pH

At its most basic level, "pH" means "power of Hydrogen". It is a logarithmic scale that describes the ratio between positively charged hydrogen ions (H^+) and negatively charged hydroxide ions (OH^-). In pure water, which sits at a seven on the pH scale, the ratio of H^+ and OH^- is equal, or 1:1. Should water have fewer H^+ ions than OH^- ions then it is described as acidic, whilst more H^+ ions than OH^- ions would be alkaline[18]. In more complex systems the acidity and alkalinity of soil is determined by the ratio of positively charged cations and negatively charged ions. For example, adding ammonium (NH_4^+) to soil increases it acidity, since it is positively charged.

§1.52 – Identify a value as recognised on a pH scale for each of the following: Neutral, High, Low.

A neutral pH would be a pH of 7. The best example of this is water, where H^+ ions and OH^- ions are equally balanced.

A high pH would be 14. This is at the end of the pH scale and describes highly alkaline substances, such as Lye - also known as sodium hydroxide (NaOH) - or potassium hydroxide (KOH) which is marketed as "pH UP" for hydroponic systems.

A low pH would be a value of 0-1. This is at the opposite end of the scale to the previously mentioned substances and describes highly acidic compounds – in fact, technically they are $1x10^{14}$ more acidic than the above. This includes the classic hydrochloric acid (HCl) as well as orthophosphoric acid (H_3PO_4) – which is marketed as "pH DOWN".

§1.53 – Identify how pH values may be changed artificially

The goal of changing the pH of soil is one of two things: increasing the pH to improve macronutrient nutrient uptake, or reducing the pH to improve micronutrient uptake.

The typical way of raising the pH of soil, typically once it falls below pH 6, if not lower, is to add agricultural lime to the soil. This is normally composed of limestone or chalk which is also known as calcium carbonate ($CaCO_3$). A mixture of finely ground and coarse particles are applied to the soil, and perhaps worked in, which helps neutralise acidity and consequently raises the pH of said soil. Another manner is by adding dolomitic lime, calcium magnesium carbonate ($CaMg(CO_3)_2$) which also provide a good source of magnesium, should it be required.

An organic way to decrease the pH of the soil, making it consequently more acidic, is to work in a source of humus or by adding nitrate solutions. An artificial means of increase the acidity of soil is by using sulphur (S), which is converted into sulphuric acid by microorganisms, or other sulphate compounds, such as ferric sulphate ($Fe_2(SO_4)_3$)[19].

§1.54 – Identify two implications for woody plants of low or high values of pH

One consequence of low pH for woody plants is the possible toxicity from magnesium, aluminium, iron and zinc. Excessively acidic soils typically increase the uptake of said molecules, leading to them

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[18] *"pH - The Power of Hydrogen", Roger McFadden,*

http://www.coastwidelabs.com/Technical%20Articles/ph__the_power_of_hydrogen.htm (19/11/2019)

[19] *"Acidifying soil", RHS, https://www.rhs.org.uk/advice/profile?PID=82 (19/11/2016)*

accumulating toxic levels of such within their tissues. A high pH, on the other hand, contributes to molybdenum toxicity. Hand in hand with this, in both cases of high and low pH, is that it reduces the uptake of various macro and micronutrients which can lead to deficiencies in parallel with toxicities.

Another implication of a low pH, and indeed a high pH, is the reduction in the activity of beneficial microorganisms, especially nitrogen fixating bacterium, in and around the rhizosphere which can be detrimental to the healthy growth of woody plants.

§1.6 – Soil Conditions Required for Woody Plant Growth

§1.61 – Identify optimum soil conditions required for growth

Four main conditions should be fulfilled if woody plants are to reach their full growth potential.

The first is, as previously mentioned, the pH of the soil. This can be artificially raised or lowered, but in general, the idea range is 6.1-7.0[20], although every plant has its particular preferences. Ericaceous plants, for example, prefer more acidic soils. The pH is a key factor in nutrient uptake.

Second is the availability of oxygen within the soil, which is directly proportional to its porosity. Ideally, loamy soils are optimum, with the structure and texture being such that air diffuses in and out of the medium with relative ease, while also holding enough accessible water to be used by the roots. On the end of this scale is low porosity, such as that found in clay soils, which typically leads to anaerobic conditions that denitrify the soil, thus reducing fertility. On the opposite end of this scale are soils with high porosity, such as sandy soils, which although they provide excellent aeration don't hold water particularly well which is detrimental to the rhizosphere in its own way.

Lastly soil temperature is another important factor. Sub-zero or post-37ºC soils are obviously harmful in their own way, but the optimum conditions within this range vary from species to species. Furthermore, in the wild the temperature of said soil varies seasonally and diurnally, and often depends on the colour, texture and structure of the soil (For example, wet soils are colder, darkly coloured earth are warmer). Steps can be taken, however, to manage soil temperature and protect the rhizosphere from damage. One means of doing so is by mulching the soil. This is where a thin layer of typically organic matter is spread atop the soil to trap heat and moisture. Although this protect the earth from heat loss, or at least slows it considerably, it can have the unintended side effect of causing it to be slow to heat back up, especially after an unusually cold winter.

The last factor is nutrition, which often coincides with a broad range of microorganisms. Even if the three conditions above are met entirely, an infertile soil would quickly kill a plant.

If these four conditions are fine-tuned – heat, pH, nutrition and temperature – as best as possible then it provides the optimum conditions for floral growth.

§1.62 – Identify a minimum of three causes of poor soil conditions

There are many ways in which soil can be rendered "poor". One of the more widespread occurrences in urban settings is soil compaction. Typically affecting clay-based soils more than sandy soils, should land become heavily traversed, either by walking, cars or otherwise, then the soil can become compacted. This compresses the pores in the soil and consequently pushes vital oxygen out and back into the atmosphere. Besides leading to anaerobic conditions relatively quickly, it can also drown roots should the soil be moist.

Another means by which soil can be degraded is by changes to the topsoil. One cause could be the stripping away of the top layer of earth which with it destroys and severs a large percentage of the rhizosphere. Since the majority of roots are contained near the surface, even a slight reduction in the topsoil can cause considerable damage.

Lastly, opposite to the aforementioned, soil can be damaged by placing an additional layer of soil on top of the soil that is already present. This naturally reduces the ability of the lower layer to be aerated and inhibits water from reaching already existing roots. Furthermore, should the new soil be of a

[20] *See 19*

different composition to the existing soil it can drastically change the earth's makeup. This may lead to compaction – in the case of clay soils placed on silty or sandy soils – or just simple mineral imbalances.

§1.63 – Identify signs and symptoms in woody plants of poor soil conditions

Many of the symptoms of poor soil conditions are shown as nutrient deficiencies. For example, in waterlogged, anaerobic conditions denitrifying bacteria can deplete the soil of nitrates and ammonium salts which lead to nitrogen deficiency within the tree's tissues. This is typically shown as chlorosis – the yellowing or discoloration of leaves. Over-fertilized soil, perhaps the result of water flows in and around the trees, can cause leaf scorch, or leaf-tip burn.

Regarding the rhizosphere, poor soil conditions can lead to root decay and stunted growth, especially in poorly aerated soils. Long term this can result in abscission, epinasty (the curling of leaves) and overproduction of adventitious roots.

When it comes to soil pH there are several different consequences of poor soil conditions. In both cases of high and low pH, outside the range typically tolerated by the organism, there is usually evidence of both nutrient deficiency and toxicity – since the rate of nutrient uptake is highly dependent of soil pH. For example, in highly acidic soils many macronutrients are poorly absorbed, while iron, aluminium and zinc are over-absorbed. Symptoms of toxicity from these three range from browning[21], stunted root growth[22], to severe chlorosis and eventually death[23], respectively. On the other end of the scale, high alkalinity can result in molybdenum toxicity which presents as the inhibition of iron and copper uptake resulting in chlorosis, wilting and widespread necrosis[24].

§1.64 – Identify a minimum of two methods of improving soil conditions for woody plant growth

There are two primary methods for improving the soil conditions of soil when it comes to waterlogging issues. The first is by the insertion of drainage pipes, as seen in a herringbone system, below the surface of the soil, at a depth of around 0.5-1m. Water can then flow into these systems and, with a good enough gradient, flow into a river or embankment. This can consequently reduce the impact of high rainfall and prevent soils from becoming waterlogged or compacted.

Another method involves sub-soiling. This is primarily used in areas where the subsoil is compacted or otherwise poorly aerated and means tilling a deep channel to break up the soil and improve its ability to drain and sustain life

§1.64 – Identify a minimum of two fertilisers for use with woody plants

As with most things agriculture-related there is a broad range of fertilisers available for use. In Dr W. F. Gericke's book "*Complete Guide to Soilless Gardening*" he advocates the use of four major fertilisers that provide the majority of macronutrients.

The first is potassium nitrate (KNO_3), also known as saltpetre. This provides both potassium and a good source of nitrates. Secondly, he advocates calcium nitrate ($Ca(NO_3)_2$) to provide a source of calcium. Next, he uses monocalcium phosphate ($CA(H_2PO_4)_2$), better known as superphosphate which is both

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[21] *"Iron Toxicity in Plants", Richard Hoyt, http://www.gardenguides.com/107453-iron-toxicity-plants.html*

[22] *"Aluminum Toxicity and Tolerance in Plant", Emmanuel Delhaize and Peter R. Ryan ,*

http://www.plantphysiol.org/content/107/2/315.full.pdf

[23] *See 14*

[24] *See 14*

organic and water soluble – as are all the chemicals Dr Gericke uses. The last part of his "recipe" is magnesium sulphate ($MgSO_4$), known as Epsom salt. Together these four compounds provide an excellent source of nitrogen, calcium, phosphorous, potassium and magnesium which would benefit woody plants just as well as general plants since it provides all the major elements in decent proportions. Of course, however, trace elements, such as boron and iron, would need to be provided separately – with the latter, along with other heavy metals, requiring chelation.

§1.64 – Describe a minimum of two methods of application of fertilisers

Two common means by which fertilisers can be distributed to woody plants is via the soil, or via foliar application.

In the former fertilisers are fed directly into the soil whereupon the nutrients can be taken up by the roots. One way of doing this is through the use of fertiliser tubes. These cells, which contain slow-release fertilisers, are driven into the ground with mallets, or placed into drilled channels, whereupon nutrients are gradually released into the soil. This method can sometimes be a beneficial long-term solution, although the number of tubes required increases with the age of the tree. This is naturally because of the rapid expansion of the rhizosphere and rising demand for nutrients from the tree as it grows larger.

Although impractical for medium to large sized trees, foliar application is beneficial to young trees. It just involves the preparation of a water-based nutrient solution which is then sprayed on the leaves. This method results in the rapid uptake of nutrients by the foliage and is consequently a useful short-term solution to a damaging issue concerning the tree. For example, iron deficiency can be corrected through the use of iron-based foliar spreads, and although it does not solve the long-term problem it does by the arborist time to fix the underlying issue.

§1.7 - Pre-Planting Soil Surveys for Woody Plants

§1.71 – List four advantages of undertaking a soil survey prior to planting woody plants

The primary advantage of conducting a soil survey before planting woody plants is to determine the suitability of the soil for the given organism. Some useful information gleaned from soil surveys includes:

- Soil pH: Extremely acidic or alkaline soils, outside the range typically tolerated (pH 5-7), may require correction before undertaking planting. This can be done artificially, as described before, or it may simply be a case of selecting species which are calcifuge (acid loving, such as *parrotia persica*[25]), or calcicole (lime-loving, such as *Acer campestre*[26]).
- Soil contamination: Soil's contaminated with high levels of heavy metals, such as boron, zinc, chromium or molybdenum may be completely unsuitable for plant life. Corrective measures could perhaps be taken at some cost, for example by removing the contaminated soil and replacing it with a fertile alternative.
- Soil texture: This can inform us to whether the soil may be prone to waterlogging, as is the case with high-clay soils, or perhaps prone to nutrient leeching, as with sandy soils.
- Soil salinity: soils with high salt contents, such as those by the sea, may be hostile to plant life due to their high osmotic pressure and low nutrient availability.

The advantages of a soil survey could thus be summarised as:

1. Telling us whether the soil required modification of correction
2. Helping us decide what species are suitable for the given location
3. What problems are likely to arise from any contaminants
4. Whether drainage systems need to be put in place

§1.72 – Describe the process of undertaking a soil survey

There are three steps, or means, by which a soil survey can be undertaken. First is by the examination of soil horizons. This can be done artificially by digging a soil pit. This is a large open area which falls deep into the ground. Through this, the different layers of soil, and their horizons can be seen by personnel entering the pit. There are dangers with this method, however, and a proper risk assessment and risk minimization procedure should be rigorously followed.

Another method is the "tactile test" which simply aims to determine the primary constituents of the soil. For example, clay soils feel sticky, while sandy soils are gritty.

Following this, or taken alone, soil auguring can be performed. Through this method a sort of screw is driven into the ground and samples are taken for every particular distance that arises therefrom. With the help of scientific analysis of the different segment, the fertility of different horizons can be evaluated.

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[25] *"Calcifuges and Calcicoles ", Edinburgh Garden School,*

http://www.edinburghgardenschool.com/2015/05/calcifuges-and-calcicoles/

[26] *"Calcicoles", RHS, https://www.rhs.org.uk/advice/profile?PID=763*

Lastly, a simple way of determining the suitability of the soil for various uses is to examine the native species present and compare their soil requirements to the data obtained from the above. For example, a calcicole species nearby would probably indicate a high pH and can be confirmed with a pH test.

§1.73 – Identify information that can be obtained from a soil survey

A proper soil survey can determine all the following:

- Soil pH
- Cation exchange capacity
- Soil fertility in the form of nutrient volume
- Osmotic pressure
- Metal content
- Pesticide, fungicide and herbicide content
- Soil texture and structure
- Water holding capacity
- Water drainage ability
- Organic matter content
- Microorganism content

§ 2

Woody Plant Phsiology

§2.1 – Taxonomy

The most important classes that exist in plant taxonomy are the lowest, most distinct divisions: Family, Genus and Species.

Family describes a group of organisms that all share a common feature and ancestor[27]. For example, the family *Fagaceae* (Beech) all have unisexual flowers, alternate, leathery, ribbed and lobed leaves one-seeded nuts that are covered by scales or spiny bur[28]. Family are broadly a collection of genera and are often identifiable in writing by their *-aceae* suffix.

The next level down is Genus. Genera are more accurate then families and are typically used to differentiate members of a family from each other, into distinct groupings. In writing genera is identifiable by the italicised and capitalised word in a two (or more) part scientific epithet. For example, *Pinus longaeva* belongs to the genus *Pinus*. A plant's flowering and seed structure typically is used to determine into which genus a plant falls within a family. For example in the family *Fagaceae*, *Quercus* (Oak) have smooth cupule nuts containing a single seed, while the related *Chrysolepis* have a spiny cupule containing many seeds.

The final traditional level is species, which distinguishes members of the same genus from each other. Species have distinct morphological differences which separate each member from each other within a genus. When written the species of a scientific epithet is identifiable by its italicised *non*-capitalised name. For example, *Pinus longaeva* (Figure 1: Pinus longaeva seedling) is the species *logaeva*. Various methods are used to determine different species; some methods are simple – such as the inability to breed with other members of the same genus – while others are more complex and related to its physical characteristics. An example of this is *Chrysolepis chrysophylla* and *Chrysolepis sempervirens*. *C. chrysophylla* is tall, growing up to 40m tall, while *C. sempervirens* is shorter than 2m. *C. chrysophylla* grows in low altitudes while *C. sempervirens* is found higher in more mountainous regions.

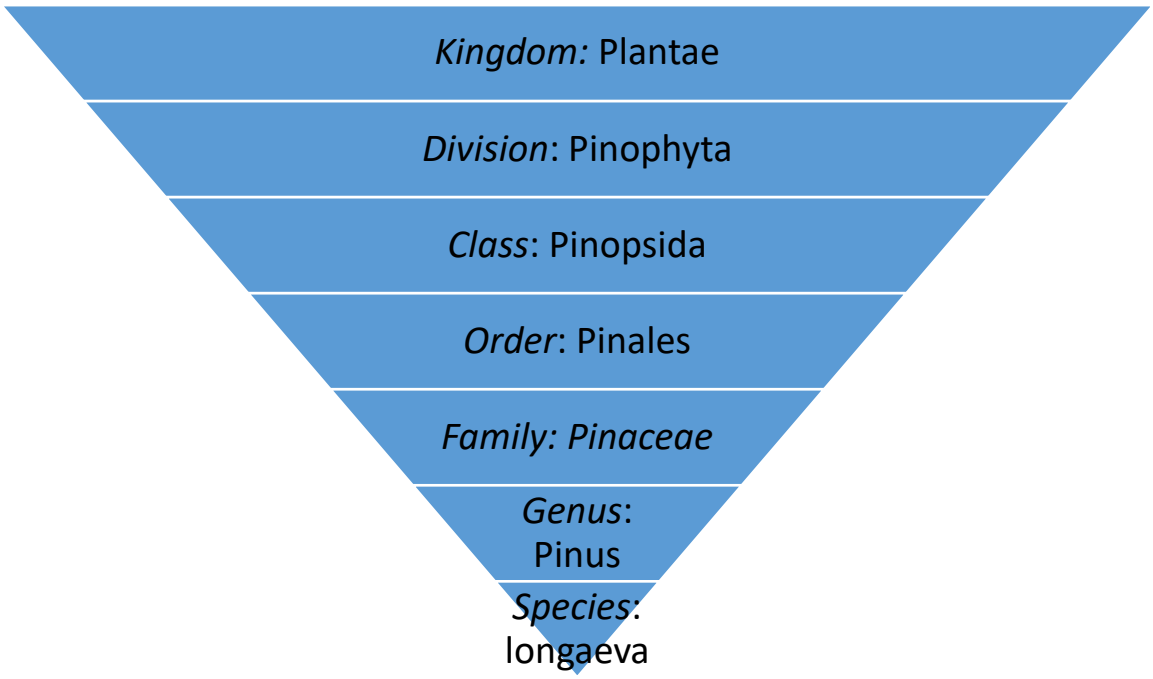


[27] *"Family", Biology Dictionary, http://www.biology-online.org/dictionary/Family*

[28] *http://science.jrank.org/pages/798/Beech-Family-Fagaceae.html*

Figure 1: Pinus longaeva seedling

Another example of the plant taxonomic ranks is shown below, for the species *Pinus longaeva*.



§2.2 – Woody Plant Cells

§2.21 – Monocot and Dicots

Historically plants were categorised into two distinct families: Monocotyledons and Dicotyledons. These are distinguished by how many cotyledons ("seed leaves") are present in the young plant. Monocots have one leaf at first (mono = one), while dicots have two leaves (di = two). There are other distinctions, however.

One is that vascular bundles in dicots are arranged close to the outermost layer of the stem, while in monocots, they exist almost randomly throughout the tree[29]. For this reason, ring-barking dicots will kill the given tree, while the same may damage but not necessarily kill a monocot.

Dicots also have primary taproots, while monocots are sustained almost entirely through adventitious roots that appear after the death of the initial taproot. [30]

§2.22 – Stems and Wood

Like most of the woody plant, and in plants in general, the stems contain a vast array of specialised cells that each serve a vital role within the plant. Some examples follow.

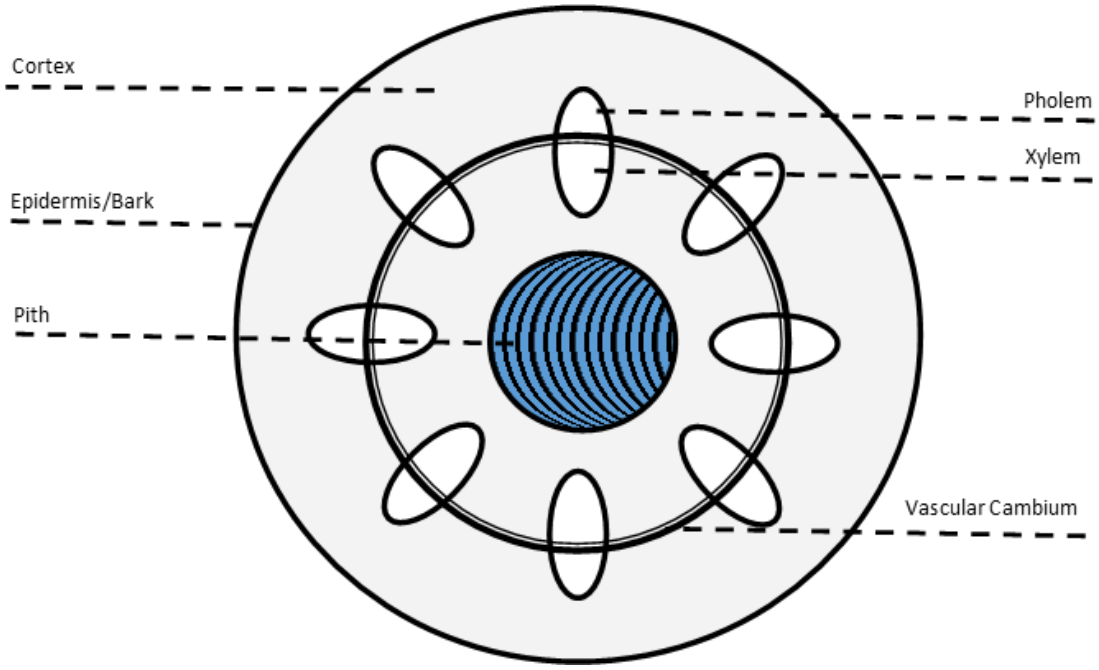


Figure 2: Cross-sectional view of a stem

Pith is "the central portion of a plant stem, consisting of loose parenchymatous tissue"[31], its primary role is to support the organism, as well as providing an energy store and transport mechanism. Typically, as a tree ages, the young pith is replaced by xylem, or simply ruptures and leaves a hollow cavity.

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[29] *"Monocotyledons versus Dicotyledons", RHS Botany for Gardeners*

[30] *See 29*

[31] *"Stem pith.", The Great Soviet Encyclopaedia, 3rd Edition.*

Parenchyma cells themselves are a broad category, but in general, it is taken to mean an undifferentiated cell that is meristematic, thus capable of division and specialisation. Their primary function is to allow for adaption to stress and the repair of damaged tissue. They can be, in a way, thought of as the stem cells of the botanical world.

The *vascular system*, which transports water, minerals and food around the plant, can be split chiefly into three types of cells: the *vascular cambium*, *phloem* and *xylem*. Phloem is one of two primary transport mechanisms within the woody plant and occurs near the outer surface of the stem. Its role is to "transport a solution rich in sugars, amino acids and hormones"[32] throughout the plant. Phloem is a two-way system, unlike xylem which only transports, in this case, water and nutrients, up from the roots. Together these two cell types function to move vital resources around the plant.

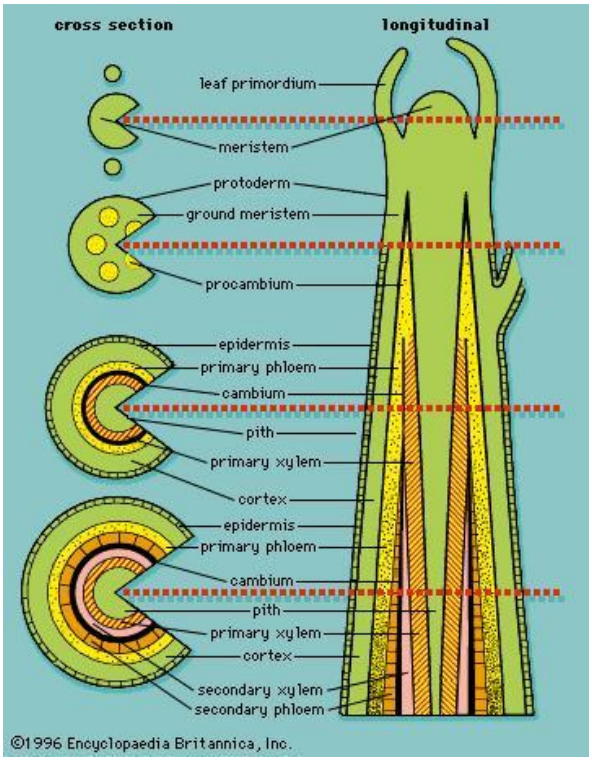


Figure 3: Stem Structure, via Encyclopædia Britannica

Typically separating the xylem and phloem is the vascular cambium. Much like the pith, the vascular cambium is meristematic and can differentiate into secondary xylem and phloem. As seen in the above figure (Figure 3: Stem Structure, via Encyclopædia Britannica) secondary vascular cells are only found in mature tissue. Vascular cambium is also found separating the pith from the cortex, and again serves the function of being able to form vascular bundles. One of the roles of the cambium is to force an increase in the size of the stems via the production of new specialised cells. Lastly, cambium can help transport nutrients laterally (from side to side, instead of up and down) via medullary rays.

A primitive form of xylem which occurs alongside such in all plants besides ferns and gymnosperms is tracheid's (Figure 4: Microscopic via of Tracheid's, via www.majordifferences.com). These can be thought of a miniature form of xylem and again serve to transport water and nutrients passively. Due to their size, they utilise capillary action for transport immensely. Tracheids are a type of dead tissue, and cannot divide.

[32] *"Nutrient and Water Distribibution", RHS Botany for Gardeners, page 96-97*

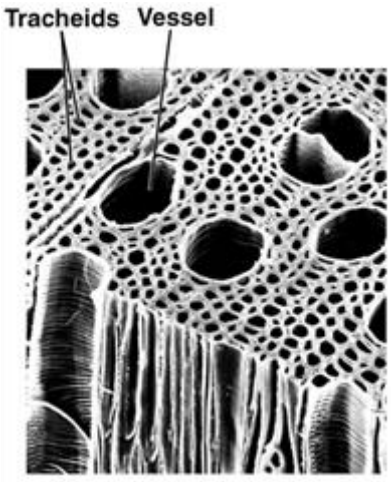


Figure 4: Microscopic via of Tracheid's, via www.majordifferences.com

On the exterior of woody plant's stem is the epidermis, which often takes the form of *bark*. The bark is composed of four principal elements: Cork (*phellem)*, *phellogen* and *phelloderm* and *secondary phloem* (Figure 5: Tree Epidermis Structure, by Brer Lappin (Public Domain)). Cork is the outmost layer and is a dead layer of robust cells which serve to protect the plant from mechanical, insect or pathological damage, as well as providing a rigid structure with which to support itself. Cork cambium, or phellogen, is the driving force behind the production of cork and is meristematic in nature. Its chief role is to produce new cork, although it also provides protection in the form of insulation as well as a buffer. For example, if a tree is cut then the open wound is filled with new cork by way of the action of phellogen. Phelloderm is parenchyma cells which differentiate into phellogen. Lastly, secondary phloem serves the same role as primary phloem, as described above, but is produced more rapidly by the vascular cambium.

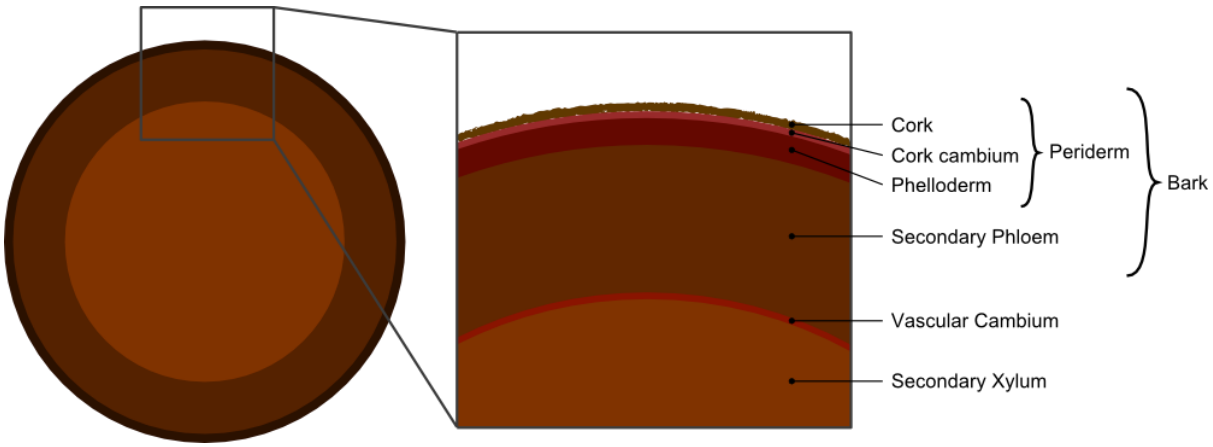


Figure 5: Tree Epidermis Structure, by Brer Lappin (Public Domain)

The classical cracked appearance of bark (Figure 6: White Pine Bark) is an indicator of some degree of maturity within the tree. In young trees bark is smooth, but as it ages and more cork is formed it begins to crack and deform. These cracks serve as *lenticels*, which are a specialised structure which has evolved to permit the diffusion of gas, such as carbon dioxide and water, through the epidermis and into the living cells within. (Figure 7: Microscopic image of the surface of Sambucus showing lenticels (in black).)

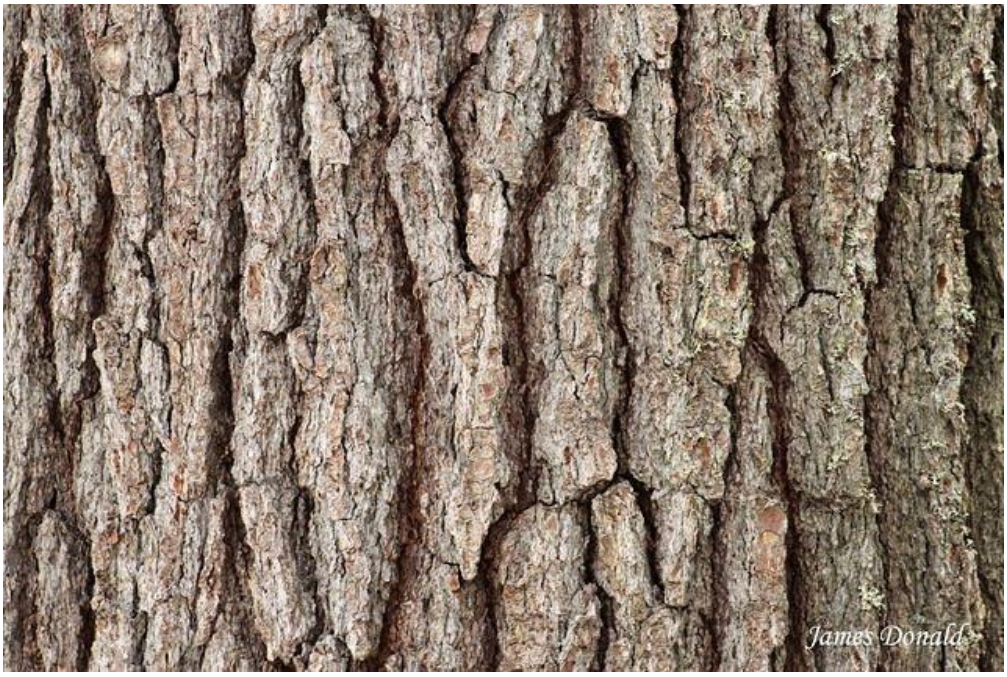


Figure 6: White Pine Bark

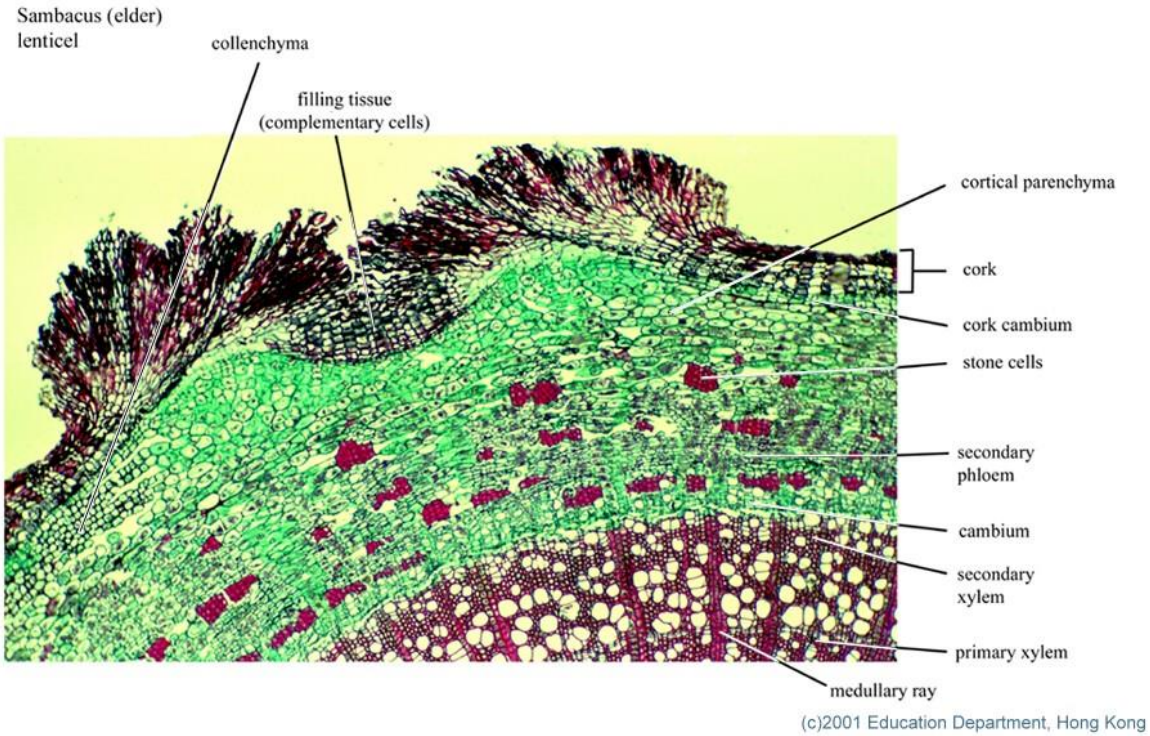


Figure 7: Microscopic image of the surface of Sambucus showing lenticels (in black).

A specialised structure found in the bark of some trees, in particular within pines and conifers[33], is *resin ducts*. These are simply secretory mechanisms that help seal wounds and prevent pathogenic invasion[34]. For example, when cut or damaged resin-producing trees will seep thick gooey resin, which consequently dries over the location and prevents infection. For comparison, it could be thought of as blood – in animal's blood serves to clot and seal a wound in the form of a scab, and likewise, resin does the same for some flora.

When cut, trees display *growth rings* – or *annual rings* – which form from the interaction between Springwood and latewood – both of which are formed at a different time in the year than the other. In essence, at least within ring-porous trees, the dark lines are formed from densely packed secondary growth, while the lighter rings which compliment this are formed from loosely packed growth (Figure 8: The types of wood, and annual rings (late wood)). The reason for this differentiation is simple: the availability of photosynthetic products. During the light season when leaves form and collect light, outward cambial growth is rapid, and thus the wood's structure is one of low density known as Springwood. When abscission begins to occur, and the basal metabolic rate of the tree begins to slow the once rapid wood growth tapers off, instead of forming densely packed cells that, to the eye, appear darker and thus produce annual rings. The following season spring-wood forms again first, continuing the cycle. The primary function of these types of wood is to promote an increase in girth, as well as providing greater structural support for additional branching growth. In other trees, such a conifers or diffuse-porous trees the annual rings are created by wood cells with thicker, lignified cell walls.

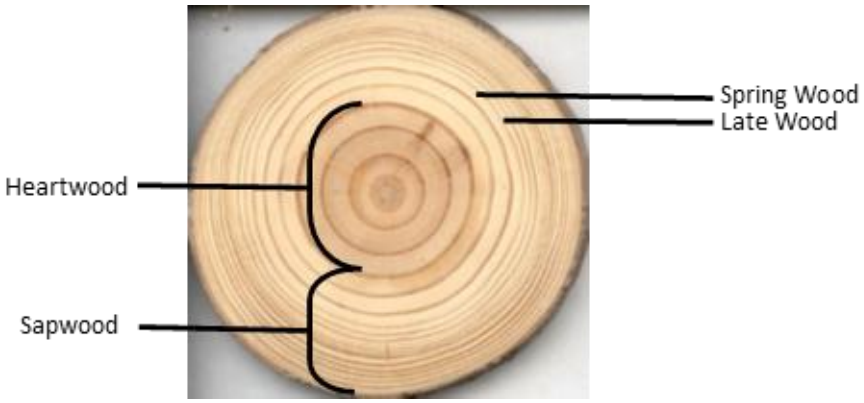


Figure 8: The types of wood, and annual rings (late wood)

In addition to this, there are two more general types of wood which cover many sets of annual rings. These are *heartwood* and *sapwood*. Heartwood is found at the centre of trees and is often a darker shade of brown compared to sapwood (as seen in Figure 8: The types of wood, and annual rings (late wood)). This is naturally dense, dead wood that has undergone chemical changes which render it highly resistant to decay[35]. Functionally this is a strong type of hardwood that serves to provide structural support to the organism, and serves no other real great purpose – indeed, many trees can survive with their heartwood removed.

Sapwood is a softer wood that is living in nature. Almost all of the trees water and nutrient conducting vessels are found within this type of timber, and it is differentiated by a lighter shade of brown compared to heartwood. Functionally sapwood serves two purposes: firstly, is also provides support (since wood is, naturally, hard), but less so than heartwood. Secondly, it is the primary means by which the tree *lives*,

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[33] *"Resin Duct", Dictonary.com, http://www.dictionary.com/browse/resin-duct*

[34] *"The Incredible Use of Resin", HubPages, http://hubpages.com/education/The-Incredible-Uses-of-Resin-From-the-Ancient-Egyptian-Mummies-to-the-Swan-Lake-Ballerinas*

[35] *Shigo, Alex. A New Tree Biology Dictionary*

so to speak, as it moves water and nutrients around the plant. The removal of sapwood thus would undoubtedly cause the death of the tree.

In addition to all this on some trees the outermost layer of the stems, the epidermis, contains a photosynthetic green layer. This is simply a weak manufacturing layer that functions to provide nutrients for the stems as well as the tree at large. Compared to the leaves themselves, however, it is poor – but during the winter it can be vital to the tree's survival if it undergoes mass abscission as in the case of deciduous species.

§2.23 – Diffuse Porous vs. Ring Porous vs. Conifers

Broadly, diffuse and ring-porous trees could be considered hardwood, while conifers are softwoods. The exact distinction is that hardwoods come from angiosperms, while softwoods come from gymnosperms[36].

The primary difference between members of the angiosperms comes in the form of transport vessel size. In ring-porous trees "the vessels laid down at the beginning of the growing season are much larger than subsequent vessels laid down at the end of the season"[37]. This is to say that the size of the xylem tubes and tracheids is some degree larger in Springwood compared to latewood. This difference results in notable concentric rings where large gaping tubes (low density) are juxtaposed with small compact vessels (High density; Figure 9: Ring Porous vs. Diffuse Porous). In comparison, diffuse porous wood presents with evenly spread tubes of roughly equal size throughout the wood. Due to capillary action, the smaller vessels present in ring porous latewood conduct water at a much greater speed and efficiency than both the spring and latewood of diffuse porous. Instead, diffuse porous wood can be considered to "diffuse" water and nutrients throughout the organism, as opposed to actively pumping it up through the wood. Due to the substantial homogeneity of both spring and latewood in diffuse porous wood, the annual rings are not so well defined, although this is not to say that they don't appear at all, just that it is thinner as the thick-walled cell layer is smaller.

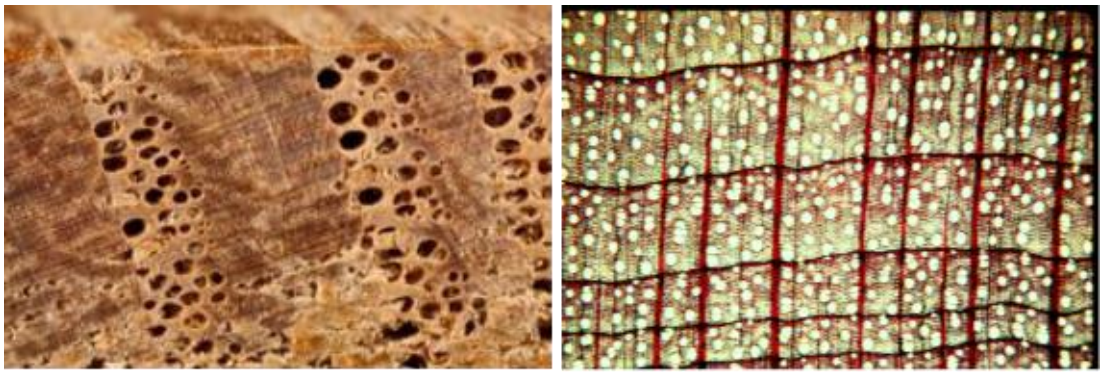


Figure 9: Ring Porous vs. Diffuse Porous

Coniferous can, in arboriculture, be defined as "any gymnospermous tree or shrub bearing cones"[38]. In a broader sense, it can be thought of as any softwood tree, and there are many differences to hardwood - non-coniferous trees - as shown in the table[39] below:

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[36] *What is the difference between a hardwood and a softwood?", How Stuff Works Science, http://science.howstuffworks.com/life/genetic/question598.htm*

[37] *"Trees, Growth Ring Formation", Encyclopaedia Britannica, https://www.britannica.com/plant/tree/Tree-structure-and-growth#ref368794*

[38] *"Coniferous Tree", The Free Dictionary, http://www.thefreedictionary.com/coniferous+tree*

[39] *Hardwood vs Softwood", Diffen, http://www.diffen.com/difference/Hardwood_vs_Softwood*

	Hardwood	Softwood
Growth Rate:	Slow	Rapid
Density:	High	Low
Leaf Shedding:	In winter	Rarely
Fire Resistance:	High	Low

At a cellular level softwood typically contains resin ducts, while hardwood does not. Softwoods have "straight radial rows of cells"[40] with straight fusiform initials, unlike hardwoods (Figure 10: Softwood vs Hardwood. In general, softwoods have a simpler cellular structure with neatly arranged cells – primary tracheids - throughout (thus making it homogeneous) while hardwoods have a more "messy" arrangement (therefore being heterogeneous) – constructed from vessels, fibres and tracheids in some case.

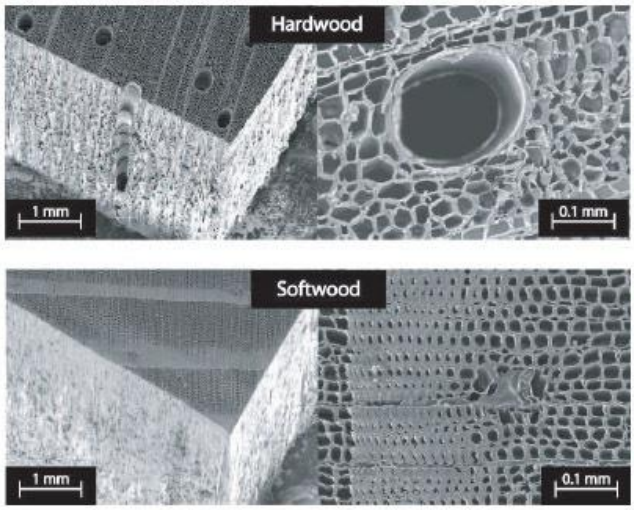


Figure 10: Softwood vs Hardwood

[40] *"Forestry 240", SF Austin State University, http://www.faculty.sfasu.edu/mcbroommatth/Lectures/Wood_Science/Lecture_5_Hardwood_Structure.PDF*

§2.3 – Woody Plant Physiological Process

§2.31 – Photosynthesis and Environmental Factors

Photosynthesis is the process whereby woody plants manufacture, or synthesise, glucose ($C_6H_{12}O_6$) using the suns light energy and a raw input of water (H_2O, drawn up through the roots) and carbon dioxide (CO_2, obtained through stomata). This process can briefly be summarised as follows:

$$12H_2O + 6CO_2 \rightarrow 6O_2 + C_6H_{12}O_6 + 6H_2O$$

(12 water + 6 carbon dioxide → 6 oxygen + glucose + 6 water)

This process primarily occurs in the leaves of woody plants in specialised structures called *chloroplasts*, where the *chlorophyll* pigment captures the light energy, principally in the 400 to 500nm wavelength range, with also some activity in the 650 to 700nm range (Figure 11: Chlorophyll et al. Light sensitivity ranges, via smartgrowtechnologies.com. Carotenoids are also involved in the photosynthetic process, but to a lesser degree.

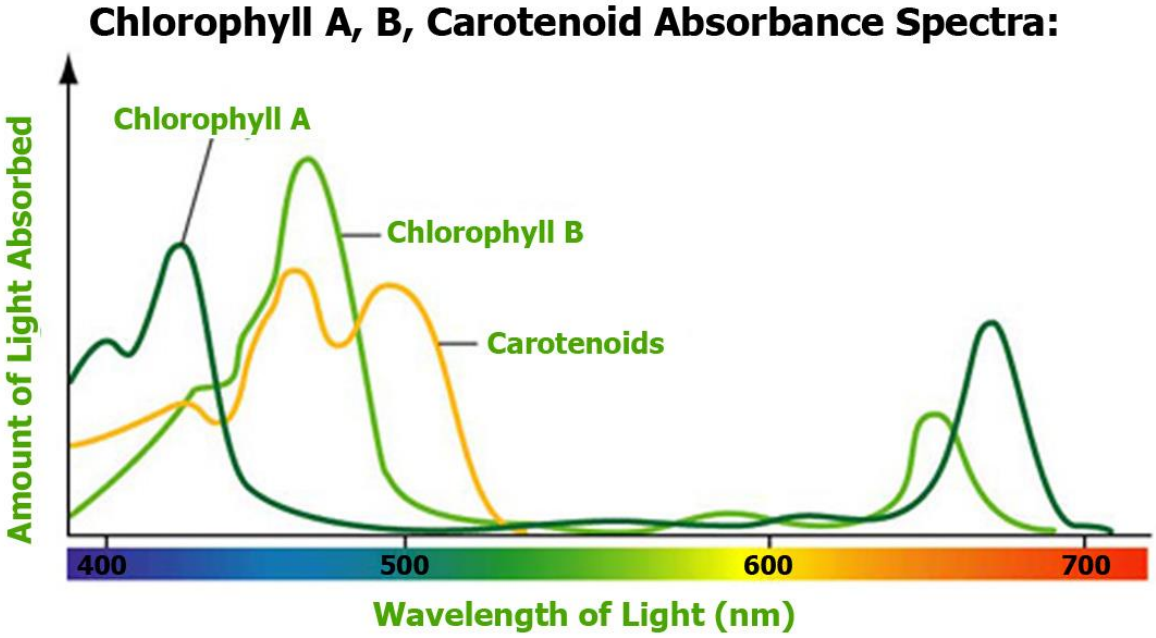


Figure 11: Chlorophyll et al. Light sensitivity ranges, via smartgrowtechnologies.com

There are two primary forms of photosynthesis – one which occurs in the presence of appropriate light (such as sunlight or artificial lamps), and one which takes place in darkness.

The former is a highly complex system whereby multiple individual parts of leafy cells interact to break water and carbon dioxide down into glucose and oxygen. This whole process is known as non-cyclic photophosphorylation (Figure 12: Non-cyclic photophosphorylation, and can be broadly be described as follows: light is absorbed by a protein known as photosystem II whereby is it eventually transported to the chlorophylic P680 which excites an electron to a higher energy state. This electron is passed onto pheophytin which consequently splits water into H^+ and O_2. This electron-molecule is then passed onto a protein called ATP synthase which then works to produce ATP (adenosine triphosphate, an energy storing molecule which fuels chemical reactions when a phosphate compound is broken from the chain) in a process called chemiosmosis**.**

In the next stage, free electrons arrive at photosystem I whereby they join a chlorophyll molecule called P700. Once again with the introduction of a light molecule, the electron is excited to an even higher energy state. Again, it is passed onto a paired acceptor molecule, this time iron-sulfur cluster proteins,

whereby it travels to a nicotinamide adenine dinucleotide phosphate ($NADP^+$) molecule whereby it consequently produces NADPH, another high energy procuring molecule which then, with ATP, goes on to manufacture further metabolites in the dark reaction cycle.[41]

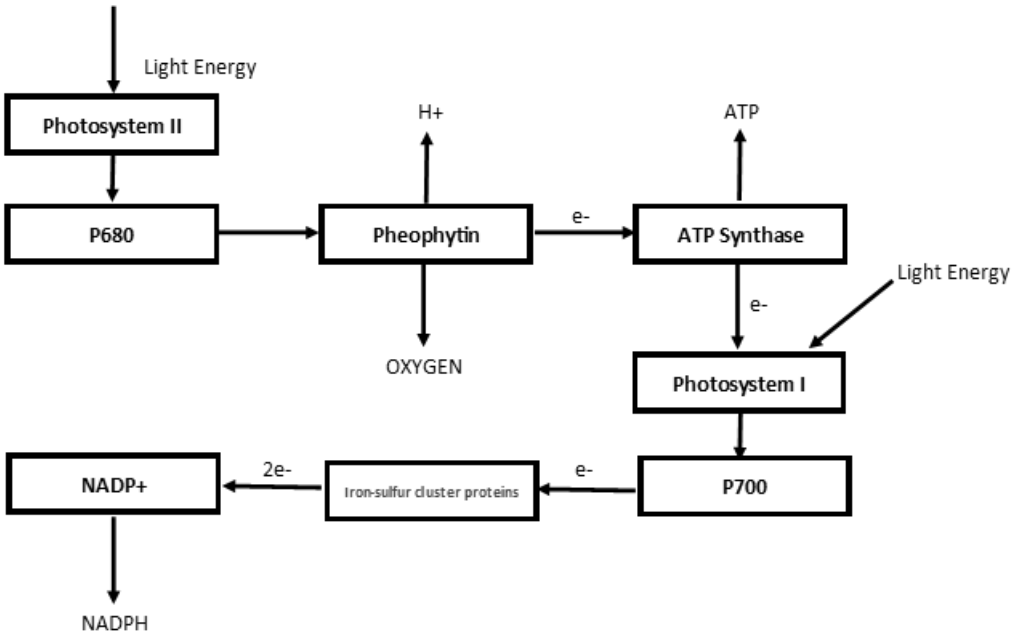


Figure 12: Non-cyclic photophosphorylation

The next stage of photosynthesis is the light-independent reaction, or dark reaction, which occurs alongside the light-dependent reaction in daylight, or on its own during darkness. The process itself is called the *Calvin Cycle* (Figure 13: Calvin Cycle– which is a little simpler than the above.

The first step is the fixation of carbon dioxide molecules with ribulose-1,5-bisphosphate (RuBP) via ribulose bisphosphate carboxylase oxygenase (RuBisCO) into 3-keto-2-carboxyarabinitol 1,5-bisphosphate (KDCaBP). This then itself quickly splits under its own steam into two molecules of 3-phosphoglyceric acid (3-PGA).

Next, using the NADPH and ATP created from the light-dependent reaction, 3-PGA is reduced into glyceraldehyde-3-phosphate (G3P). In this stage, NADPH donates an electron to form G3P, and thus consequently returns to $NADP^+$. Lastly, a fraction of G3P comes together to form glucose, while the majority goes on to recreate more RuBP, which thus completes the cycle[42]. This whole cycle can be broadly be described chemically as:

$$6\ CO_2 + 6\ RuBP + 12\ ATP + 12\ NADPH \rightarrow 12\ G3P$$

$$10\ G3P + 6\ ATP \rightarrow 6\ RuBP$$

$$2\ G3P \rightarrow C_6H_{12}O_6$$

[41] *"The Light Dependent Reaction", Khan Academy, https://www.khanacademy.org/science/biology/photosynthesis-in-plants/the-light-dependent-reactions-of-photosynthesis/a/light-dependent-reactions*

[42] *"The Calvin Cycle", Khan Academy, https://www.khanacademy.org/science/biology/photosynthesis-in-plants/the-calvin-cycle-reactions/a/calvin-cycle*

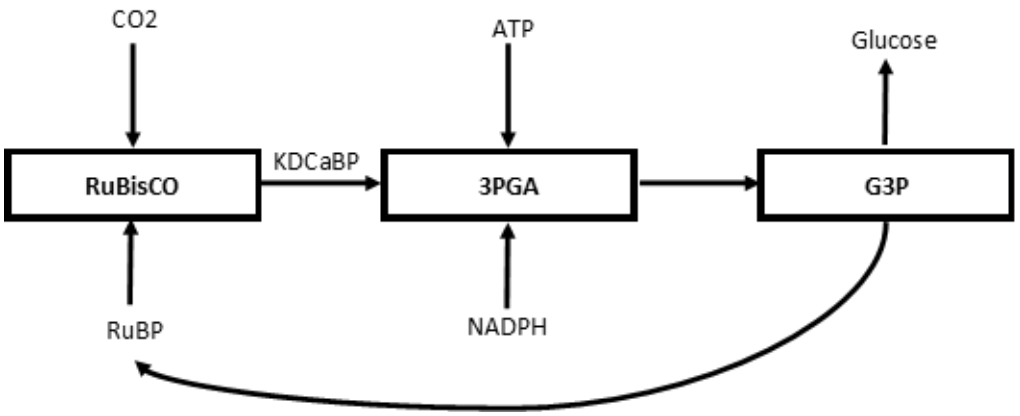


Figure 13: Calvin Cycle

It is worth noting that during this whole cycle, and the light dependent reaction, which is vastly more complicated than as described above, there are many more intermediate products and inputs. For example, adenosine diphosphate (ADP, ATP minus a phosphate group) is a required input in the light dependent reaction and is produced in the Calvin cycle when ATP is utilised. Another "waste" product is oxygen, which is produced from the breakdown of CO_2 by RuBisCO. All in all, the two systems are harmonious and work with each other to build the core building blocks from photosynthesis.

When it comes to environmental factors that influence photosynthesis, we can see the majority from the two diagrams above. These are, naturally, the raw inputs to both reactions.

First of all, we have sunlight (or artificial light). A lack of light, or light with the incorrect spectra, will naturally lead to deficiencies within the light dependent reaction, which will reduce the manufactured products that are required to fuel the Calvin Cycle. Higher volumes of light equal increased activity at photosystem I and II, leading to an increase in the production of ATP and NADPH. This in turn helps fuel the reduction of 3PGA into G3P and consequently glucose.

Another environmental factor is carbon dioxide. This is chiefly required for the Calvin Cycle, and deficiencies will naturally manifest with a decrease in the production of glucose. In artificial settings atmospheric CO_2 can be increased (Figure 14: A natural, fungus-based, CO2 enrichment device) to enhance the growth of plants, including woody plants. For example, although natural atmospheric CO_2 is around 400ppm, there is some evidence that many plants can utilise up to 1400-1600ppm[43] - with effects plateauing at around 1000ppm – (Figure 15: Relationship between CO2 levels and growth)

The last major environmental factor involved with photosynthesis is water (H_2O). Ignoring the physical, cellular need for water, we can tell from the above that it is necessary for the light dependent reaction. It is broken down into H^+ and O_2, which frees up an excited electron for use later in the manufacturing process. On a more basic level should soil based water become depleted then plants close their stomata which impair the ability for CO_2 to enter the leaves and fuel the Calvin Cycle. Too much water and the ion ratio within the chloroplasts can become unbalanced, leading to an inability to transport excited electrons from photosystem II to photosystem I.

The last factor worth mentioning is temperature. A $10^{O}C$ temperature increase broadly doubles the rate at which photosynthesis occurs – up unto a point, depending on species, where the temperature starts to sharply impair the ability to create glucose.

[43] *"CO2 in Greenhouses", T.J Blom et al., http://www.omafra.gov.on.ca/english/crops/facts/00-077.htm*

All in all the rate of plant photosynthesis is only as fast as the slowest element. For example, in a CO_2 enriched greenhouse, with plenty of water and a proper temperature but inadequate sunlight, photosynthesis will only proceed as fast as the weakest element allows it: sunlight.



Figure 14: A natural, fungus-based, CO2 enrichment device

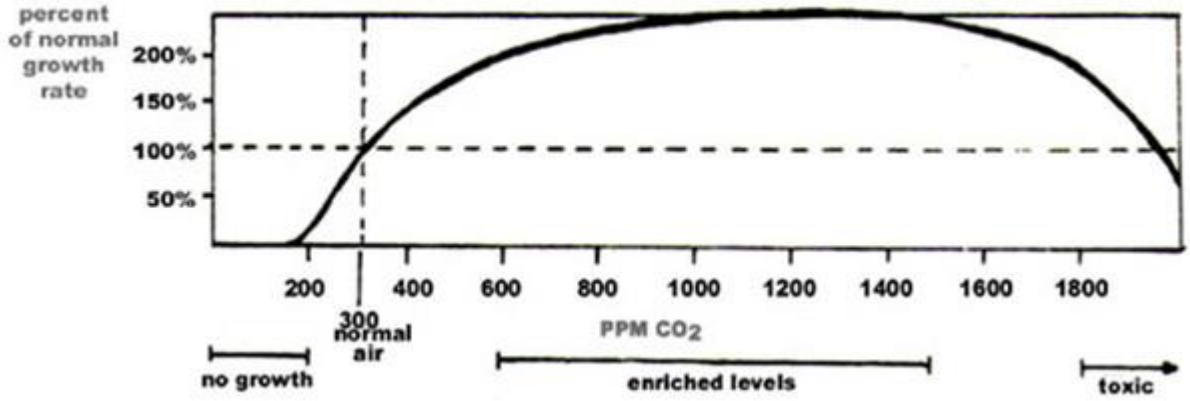


Figure 15: Relationship between CO2 levels and growth, via matadorco2.com

§2.32 – Respiration and Environmental Factors

Plant respiration can be broadly explained as the utilisation of sugars, formed from photosynthesis, to create energy by which more complex compounds can be produced. Respiration takes two forms: glycolysis and the Krebs' Cycle.

Glycolysis is the breakdown of glucose ($C_6H_{12}O_6$) into pyruvic acid which results in a net gain of adenosine triphosphate (ATP), which as described before is the energy-carrying molecule of most living organisms. The breakdown of ATP into adenosine diphosphate (ADP), and perhaps even adenosine monophosphate (AMP) releases small amounts of energy within the cells that can be used to drive physiological processes.

The actual process of *aerobic* glycolysis is both long-winded and complicated, but it can be described simply by the following chemical equation:

$$C_6H_{12}O_6 + 2\ NAD^+ + 2\ ADP + 2\ P_i \rightarrow 2\ \text{Pyruvic acid} + 2\ NADH + 2\ H^+ + 2\ ATP + 2\ H_2O$$ [44]

This tells us that with an input of glucose, nicotinamide adenine dinucleotide ions (NAD^+), adenosine diphosphate (ADP) and phosphate, the enzyme catalysed aerobic glycolysis process creates pyruvic acid, NADH, hydrogen ions, adenosine triphosphate (ATP) and water (H_2O). All the raw inputs of glycolysis are produced from photosynthesis, besides NAD^+ which is created from a complex reaction involving oxygen taken from the air.

Regardless, the primary product of this reaction, pyruvic acid, eventually enters the Krebs' Cycle after being oxidised into acetyl co-enzyme A (CoA). The Krebs' cycle is another marvelously complex system which I shan't go into great detail about, however as we can see from the below diagram (Figure 16: "Oxidation of pyruvate and citric acid cycle" by OpenStax College, Biology) the whole process releases a fair amount of the energy carriers: NADH, $FADH_2$ [45]and GTP (which for our purposes is interchangeable with ATP, the only difference being a guanine group instead of an adenosine group). This cycle happens twice for every glycolysis reaction as we can see from the equation above which produces two pyruvic acid molecules.

[44] *"Glycolysis", Wikipedia.org*

[45] *NADH and $FADH_2$ are made into ATP by oxidative phosphorylation later on.*

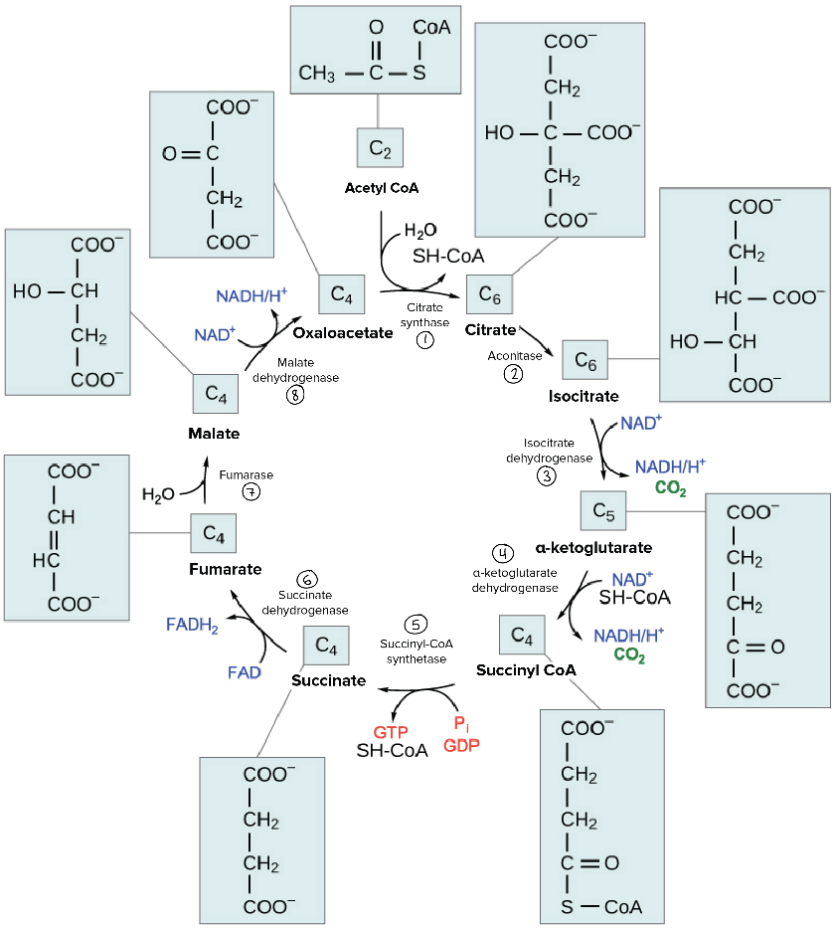


Figure 16: "Oxidation of pyruvate and citric acid cycle" by OpenStax College, Biology

It is worth also noting the production of water (H_2O) and carbon dioxide (CO_2) from this cycle. In a way, then, respiration can be thought of as the opposite of photosynthesis. Whereby the later utilised water and carbon dioxide to produce energy, glucose and oxygen, respiration uses these to create water, energy and carbon dioxide. (The relationship can be seen in Figure 19: Photosynthesis and Respiration)

Regardless, as with photosynthesis, there is a broad range of environmental factors that can influence the respiration process. The three I shall discuss are oxygen, hydration and carbon dioxide.

The former, oxygen, plays a vital role in the Krebs' cycle, although it may not be apparent from the diagram above. Its primary role is in oxidative phosphorylation of NADH and $FADH_2$ into ATP[46]. A steady supply of oxygen is thus required to ensure a high output of ATP from the Krebs' cycle, and should factors such as pollution be dominant than a reduction in energy, and thus growth will result. Another way in which thus may result is if the temperature is too high, at which point stomata will close impairing the ability for oxygen to flow into the plant.

Hydration is another limiting factor in respiration, but not for the obvious reason. To put it simply, too much water impairs *aerobic* respiration and causes an organism to default to *anaerobic* respiration, also known as anaerobiosis. Although for the most part, this yields the same result, namely the production of ATP, it is far less efficient and can also lead to the creation of toxic compounds within the plant, such as ethylene and acetaldehyde. Although anaerobiosis can be maintained for a short period, the

[46] *"Oxidative phosphorylation", Khan Academy, https://www.khanacademy.org/science/biology/cellular-respiration-and-fermentation/oxidative-phosphorylation/a/oxidative-phosphorylation-etc*

long-term consequences are the stunting of growth, leaf abscission or even the death of the organism. For this reason, hydration needs to be carefully balanced between providing enough water for photosynthesis, while at the same time not encouraging anaerobiosis.



Figure 17: Small air circulation fan

Lastly, carbon dioxide plays a minor role in the rate of respiration. Unlike photosynthesis where carbon dioxide is a vital compound, with respiration, it is a waste product. Unless it is removed from the plant, it would quickly reduce the rate at which respiration occurs. For example, in my own artificial environment where I grow *Capsaicin annum* it is necessary to have a small fan moving air (Figure 17: Small air circulation fan) from around the leaves. If this was not done and the air left to be still with no movement, then the waste carbon dioxide from the Krebs' cycle would simply sit around the stomata of the leaves blocking the entrance through which necessary oxygen passes through. For this reason, poor air circulation or simply an inability – for whatever reason – for a plant to excrete carbon dioxide would lead to a sharp reduction in the ability of the organism to respire.

§2.33 – Transpiration Stream and Environmental Factors

The transpiration stream essentially describes the movement of water through the plant from the roots to the leaves (Figure 18: The Transpiration Stream).

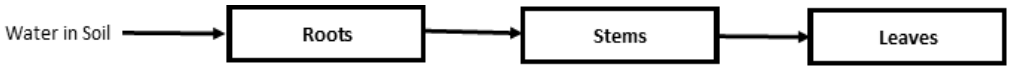


Figure 18: The Transpiration Stream

In the beginning, water moves into the roots through the symplast pathway, and then this water is moved up through the xylem to the leaves, where it eventually transpires out of the stomata. Although in smaller plants capillary action can account for the movement of water up through a plant's stem, in larger plants, such as trees, it is believed to be caused by a pulling force that occurs when water exits the leaves. The best way to think of it is that when a water molecule in a leaf is lost to the air, then this creates a small

vacuum within the stem, whereby a water molecule is pulled into and up. The surface tension of the water and its desire to be next to other water molecules (cohesion) also contributes to this pulling force (this is known as the Cohesion-Tension theory).

Although the clear majority of water taken in by the roots is lost again through transpiration, it's movement helps transport minerals and compounds throughout the plant, as well as providing the vital water that we have seen is necessary for photosynthesis.

The exact rate of transpiration is related to the relative humidity of the surrounding air – the water vapour concentration gradient - and this is indeed one of the environmental factors that influence the transpiration stream. Air with 0% humidity can be thought of as extremely drying. With a lack of moisture in the air there is great potential for water to be sucked out of a plant, so to speak. In this situation, many plants close their stomata to prevent excessive water loss. Conversely, at 100% humidity there is essentially "no room" for any more water in the air, and so transpiration is extremely slow if it occurs at all – thus the transpiration stream stops. The ideal humidity for most plants is around 50%[47].

Another environmental factor is the salt concentration of the soil substrate. Water moves into the roots through osmosis – which can be thought of as the desire for the salt concentration of two adjacent liquids to be equal. In normal circumstances, the soil has a high water content and low salt content, while cells have a low moisture content and high salt content. This creates osmotic pressure from the willingness of water to flow from the soil into the roots to balance the salt/water concentration. The makeup of the cellular wall prevents the salts themselves moving from one medium to the other, instead only water can pass through. Because of this if the salt content of the soil is too high, or at least greater than that of the plant cells, then the water has a natural inclination to move *out* of the cell into the xylem and eventually into the soil. This leads to rapid water loss in the organism and will eventually lead to wilting, and even death as the transpiration stream is reversed or stopped.

Lastly another paradoxical environmental factor is water. If there is a lack of water within an organism, the stomata tend to close to restrict further water loss. This closing of the stomata then reduces the ability for the plant to transpire (as well as photosynthesize and respire). This consequently leads to further problems down the line.

§2.33 – Plant Adaptions to Physiological Processes

There are only limited ways in which plants may adapt to optimise their physiological processes, due to the immobile atrophic nature of the organisms. The main way all three of the above processes can be tuned is by modulating the opening and closing of the stomata.

During photosynthesis, open stomata allow the absorption of carbon dioxide which is necessary for the reactions that consequently take place. During respiration, there is a need to have a means by which waste carbon dioxide can be excreted, and fresh oxygen inhaled. Lastly, during transpiration, open stoma are required to move water and minerals from the roots up unto the leaves where they can be utilised. For this reason, should any environmental factor surrounding a plant be unfavourable the stoma can close (or open) to optimise the process. For example, if we look at the following diagram showing the relationship between photosynthesis and respiration (Figure 19: Photosynthesis and Respiration), then we can see that there are only three raw inputs that can be optimised since light input is not able to be modified. These are water, carbon dioxide and oxygen.

[47] *"Temperature and Humidity", The Healing Canna, http://thehealingcanna.com/temperature-humidity/*

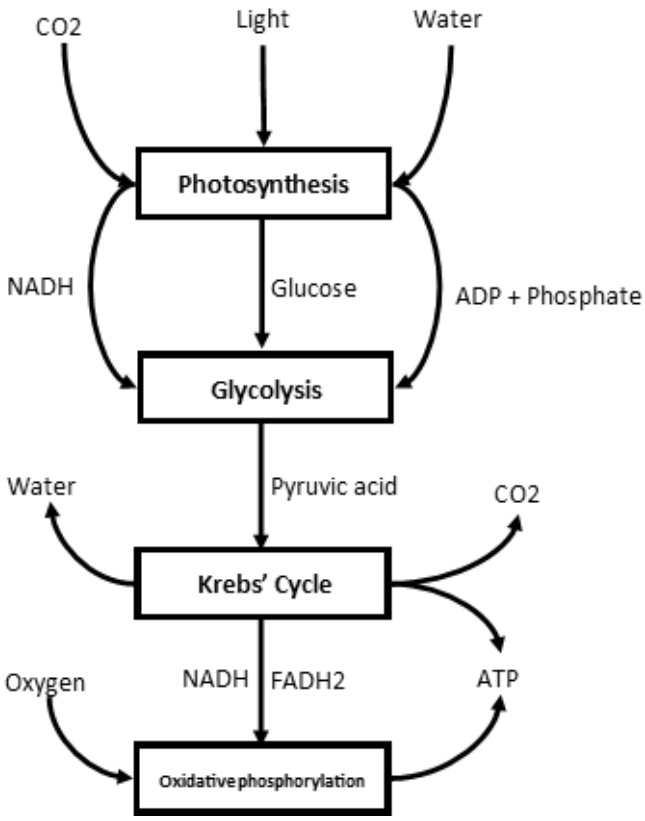


Figure 19: Photosynthesis and Respiration

Both oxygen and carbon dioxide concentrations are regulated by the opening and closing of the stoma, while water is adjusted by changing intracellular salt concentration. Lastly, a common way for plants to adapt to their environment in regards to water and nutrients, especially with many trees in winter, is for their leaves to undergo abscission.

When leaves drop, there is an immediate reduction in the water and air requirements for the plants. For example, in a cold winter where there is perhaps little rainfall, and that which does fall freezes, having little to no leaves provides an evolutionary advantage in that the water requirements for the woody plant are reduced significantly. This allows trees to harden and survive harsh winters and be prepared for spring. Furthermore, many winters are accompanied by low humidity which would also drain an organism of what little water it has. Once again through abscission, a plant reduces the impact of such a weather pattern.

§2.34 – Kinetic and Potential Energy within a Woody Plant

As we discussed the physical and chemical inputs for transpiration, photosynthesis and respiration earlier, it is worth describing the types of energy that is stored within such.

First of all, during photosynthesis, which has a raw chemical input of carbon dioxide and water, potential energy is created when ADP and ATP are formed. In these molecules, there are weak but high energy bonds linking phosphates to adenosine. This weakness incurs an easy potential for them to break and release the energy stored within. Thus, adenosine triphosphate is an example of potential chemical energy.

During respiration, a similar form of potential energy is created. This time with pyruvic acid. Through the creation of such in glycolysis a great deal of potential energy is set up within the pyruvic acid

molecule. Once in the Krebs' cycle, this potential energy is released by catalytic enzymes to form new high-energy molecules: NADH, $FADH_2$ and more ATP. These too have high potential chemical energy.

Lastly, during the transpiration stream, a different form of energy is created: kinetic energy. Although small, the movement of water up the xylem creates both osmotic pressure and cohesion-tension movement which translocates water and nutrients around the organism. This movement is a form of kinetic energy.

Broadly potential energy can be described as the *potential* energy that can be released in some form. For plants, this is mainly seen in the shape of potential chemical energy, which is the possibility of some given molecule to produce a net gain in energy when modified. Another form is gravitational potential energy which is the energy that the branches of many large trees may experience. Should a branch snap then this gravitational potential energy is turned into kinetic energy – the energy of movement. Put simply, if something has the potential to turn energy into actual energy, then it is described as potential energy. Should something be actively creating energy, such as a falling branch accelerating through gravity, then it can be described as kinetic.

§2.35 – Dynamic and Static Mass

Although trees can be thought of as static since they are immobile, they are nonetheless at the whims of dynamic forces. Broadly static mass is the mass of, say, a branch when there is no movement. Should there be movement, or additional stress placed upon the organism, then the tree begins to experience dynamic mass – which is the mass encountered by a given part when motion is applied.

For example, take the branch of a large tree. Let's say it has a mass of 100kg. In a vacuum, it's static weight is 100kg. In the real world, however, there are other forces applied. The wnd, for example, may exert such force that its dynamic mass approaches 150kg or more. For the arborist, this is relevant because when cutting or removing branches one needs to make rough estimates of the weight and take appropriate precautions.

§2.4 – The Principles Applied to the Growth of Woody Plants

§2.41 – Phenology and a Typical Developmental Year for a Woody Plant

Phenology is best described as "the scientific study of periodic biological phenomena"[48] – which in our case can be taken to mean the study of the timings and seasonal occurrences of woody plant processes, such as blooming and leaf abscission.

One deciduous species, *Quercus robur,* undergoes – like most species – five stages within a yearly cycle, although environmental conditions may modify the exact time of onset.

The first stage, which can be considered in some ways the extension of the final stage, is that of a period of dormancy which occurs during winter, peaking at around the winter solstice. During the early half of this juncture, a tree is, for the most part, inactive. Physiologically during this period trees are concluding with abscission and entering a brief period of dormancy before preparing for the spring. I have noted, however, with a local Ash trees that they begin to drop their distinctive seeds after their leaves have abscised and well into the deep winter. Regardless, during the second half of this stage, the tree will begin to use it's remaining energy reserves to produce new feeder roots which will eventually spur the growth of new leaves and buds.

The second stage is that which occur in early spring to mid-summer. During this stage, woody plants, at this point primarily fed by feeder roots, begin to break dormancy in a period known as bud break. This is a time where new foliage and blossom starts to form, and photosynthetic processes are ignited and beginning to provide energy to the newly awakened organism. As this process proceeds, it accelerates up unto the third phonological period.

That next stage involves the maturation of leaves and the termination of new bud growth. Occurring from mid-summer to autumn photosynthetic activity peaks during the summer solstice and continues onwards into the winter. This is a time where the ability for trees - full of mature foliage – to gather light is at its maximum, and consequently growth is at its fastest. That is to say that there is relatively rapid radial growth of branches, trunks, stems and shoots.

The fourth stage, beginning to occur in late summer, is one of preparation - whereby large food stores are built up in anticipation of the incoming winter. Non-woody roots disintegrate as their survival is not likely during harsh frosty winters, and for the most part, growth ceases and secondary growth of wood becomes denser – thus producing latewood.

The final stage, which overlaps with the first, is visible by an extended period of leaf abscission. Besides leaf drop, there is also the replacement of spring feeder roots by new roots in preparation for dormancy. After this stage, and entering winter, food reserves within the organism are at their highest.

§2.42 – Seasons of Potential Weakness in Woody Plants

They are two primary seasons in which woody plants, and indeed plants in general, may frequently be liable to undergo stress which potentially results in damage, extensive or otherwise. Broadly these are winter and spring, although more correctly I'd argue that late autumn and early spring, along with the whole of winter, is apter.

During both late autumn and early spring there is a good chance of unseasonal frost occurring. As the plant has yet to enter a dormant state and is, in a way, quite vulnerable due to widespread physiological changes, the presence of hoar (visible) or black (invisible) frost can easily damage plants which would

[48] *"Phenology", The Free Dictionary, http://www.thefreedictionary.com/phenology*

not have the capacity to adequately respond due to a low photosynthetic rate and, in spring, rapid growth and the depletion of energy reserves.

In winter the cause of damage is obvious: freezing conditions and severe, long-lasting frost. Naturally, in a dormant state, the woody plant would hardly have the capabilities to respond to damage, and should it do so it may deplete vital energy reserves which would impact development during the spring. In non-cold hardy plants, the primary cause of harm from frost in all seasons is frost plasmolysism, which is a state of dehydration caused by water being drawn out of cellular protoplasm via osmosis due to the formation of intercellular ice.

Furthermore, unseasonably hot weather during winter combined with low humidity can lead to desiccation – a state of extreme water loss caused by rapid transpiration. An example of when this occur is during rapid heating after a period of freezing temperatures, when the soil is still frozen and water unavailable. The organism warms, and in low humidity water is transpired from the plant faster than the roots can draw up water (as it is mostly frozen), leading to desiccation.

§2.43 – Germination of Pinus longaeva

For the Great Basin Bristlecone Pine (*Pinus longaeva*, Figure 20: Pinus longaeva seedlings showing epigeal germination of a conifer) there are a few conditions that must be satisfied for their seeds to germinate. Unlike many other species, however, stratification is not required, although scarification is, as discussed below.



Figure 20: Pinus longaeva seedlings showing epigeal germination of a conifer

The first and most obvious requirement for germination are that the seed is viable. Although they may appear almost inert, seeds are nonetheless living organisms and should be treated as such and not exposed to extremes in temperature (unless required), acids, crushing or so on.

Secondly, in the case of *Pinus longaeva*, they need weak scarification. Per some sources, soaking in water or a weak acid solution for at least 24 hours before sowing is required. From my experience, however, this is unnecessary. Given that the native range of *Pinus longaeva* is prone to dry, drought-stricken winters, some soaking is necessary to mimic the wet springs and summer they are used to – however a mere 30 minutes in a weak solution of Superthrive is all that appears to be necessary (and, indeed, even the Superthrive is only a preference rather than a requirement) – as I had a high 90% germination rate with such treatments.

Thirdly, soil pH and nutrient availability are also mostly unnecessary, although it is desirable. Evidence has shown[49] that *P. longaeva* typically establishes itself in poor soils where other species struggle to grow. In particular, they are found in soils derived from limestone or dolomite. During my experiments with the species, I discovered that they had no preference to either – with seeds planted in either high, low or mixed limestone or dolomitic soils germinating perfectly well. The greatest vigour, however, was found in pH neutral peat – but in regards to the previous point, germination rates were identical for all, besides soils with a pH of above 8.5, which is to be expected. Thus it could be said that the tree requires soil of pH 8.5 or less to germinate.

As for last points, *P. longaeva* also does not need light to break dormancy – so prefers to be covered when sowed – and also can tolerate moderately high temperatures.

§2.44 – Secondary Thickening and the Increase in Girth

Secondary growth, or secondary thickening, is best described as the lateral growth of tissue arising from the vascular cambium and cork cambium. For comparison, primary growth emerges perpendicular to the resting plane – such as at the tip of branches and shoots – and stems from meristematic parenchyma.

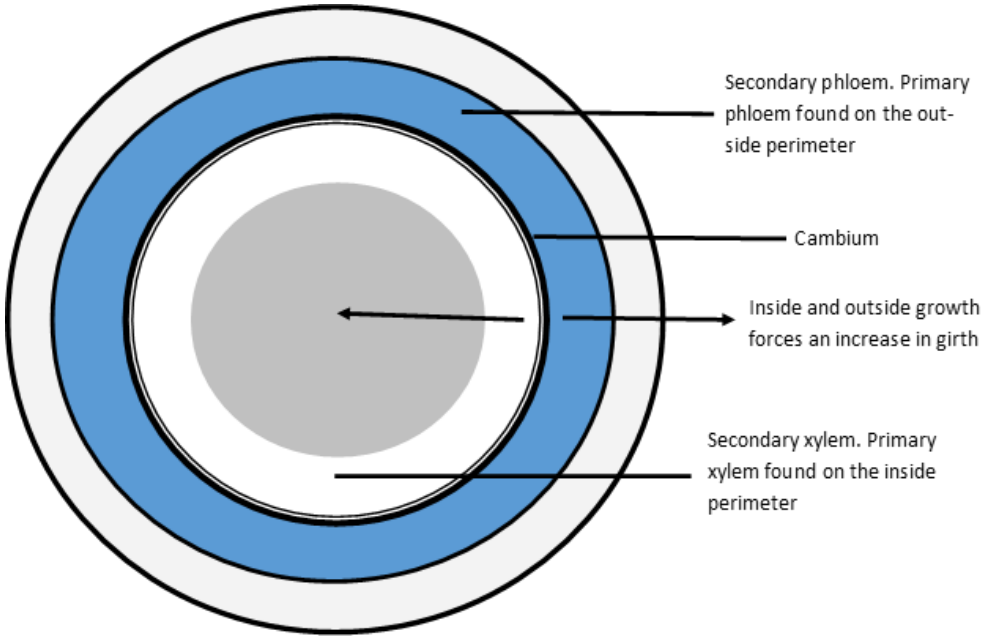


Figure 21: Secondary Growth

[49] *https://www.fs.fed.us/database/feis/plants/tree/pinlon/all.html*

Secondary growth itself is what causes an increase in the girth of a woody plant (Figure 21: Secondary Growth). The vascular cambium is, for our purposes, found in a ring around the centre of a trunk or branch. On the inside edge, secondary xylem is produced. This naturally creates an outwards pressure as the volume of xylem tissue increases. Secondly, on the outside edge of the vascular cambium, secondary phloem is manufactured. This one again causes an increase in tissue that expands the diameter of the trunk or otherwise. Both these systems push outwards and consequently, lead to an increase in girth.

One way to imagine this is using the idea of a balloon. To start with the balloon is deflated, and this can be compared to the immature stem which is comprised of only primary xylem and phloem, amongst other components such as a cortex. In this example, the cambium is the balloon itself. When inflated, the balloon expands, and likewise, when secondary xylem is produced on the inside edge of the cambium, it too forces expansion. To take it a step further, secondary phloem is produced on the outside of the balloon, best imagined as the rubber material growing thicker as it is blown up, which further increase the girth.

§2.45 – Pollination and Fertilisation

All species of woody angiosperms and gymnosperms reproduce sexually. In essence meiotic (containing half the number of required chromosomes) male and female gametes, termed sperm and ovum respectively, must fuse to form a zygote which will go on to develop into a seed. This fusing of gametes is called fertilisation, and it occurs after pollination.

Pollination is simply the act of pollen arising from the terminal anthers of the androecium – landing upon and "fertilising" the stigma of the gynoecium. Once it has arrived the pollen travels down the pollen tube, the style, and into the ovule whereupon it fuses its nucleic genetic material with the ovum to produce a zygote. It's worth noting that only angiosperms have an ovary covering the ovule[50].

§2.46 – Monoecious and Dioecious

Although the general structure and behaviour of woody plants when it comes to fertilisation in the same, the actual specifics vary from species to species. For example, some species are bisexual, whereby both gynoecium and androecium occur within the same flower on the same plant. An example of this is *Malus pumila* (Apple). Although in many case this allows for an ability to self-pollinate, some trees, such as the aforementioned *M. pumila*, are self-incompatible and must cross breed, while other such as *Crataegus monogyna* (Common Hawthorn) can self-pollinate (Figure 22: Crataegus monogyna flower, credit: Ben Legler).



Figure 22: Crataegus monogyna flower, credit: Ben Legler

[50] *"Botany for Gardeners", RHS, page 22.*

Most native British trees are, however, unisexual – and this specification can be broken down into various distinct classes, but the most prevalent and important are monoecious and dioecious trees. Unisexual itself declares that each flower contains *only* either gynoecium or androecium, but never both together.

Monoecious trees, such as *Quercus robur* (Oak) and the majority of *Pinophyta* (Conifers) such as *Taxus baccata* (Yew), have male and female flowers separate, but on the same plant. This naturally leads to the possibility of self-pollination.

Dioecious trees, such as *Populus tremula* (Aspen) and *Ilex aquifolium* (Holly), have male and female flowers on different trees – that is, male and female trees are separate. This consequently forces cross-pollination.



Figure 23: Holly, showing male (above) and female (below) flower structure.

There are actually some other "plant reproductive morphologies"[51] that can demarcate the finer points of a tree's behaviour, but in general, the three above classifications are broad enough to loosely include most species.

§2.47 – Woody Plant Seed Dispersal

There are, ultimately, limitless ways by which trees, and plants in general, have evolved to disperse their seeds. One of the most common is anemochory - or dispersal by the wind. Typically trees which utilise this method have evolved specialised structures that are designed to capture or harness the wind to move their seeds away from the parent plant and into fertile land. An example of this is *Acer*

[51] *"Plant reproductive morphology", Wikipedia, https://en.wikipedia.org/wiki/Plant_reproductive_morphology*

pseudoplatanus (Sycamore) which have elongated pericarps that act as "wings" to carry the seeds (Figure 24: Sycamore Seed showing extended pericarps. Credit: Worksonpaperart, Etsy.com).

Other methods of seed dispersal include hydrochory – water dispersal – as seen with species of Mangroves. Zoochory, or animal dispersal, is seen with many species such as *Quercus* (Oak) and it's harmonious relationship with Squirrels who move their seeds through endozoochoric processes. Even more, specifically myrmecochory is dispersal by ants. Lastly, we have all the autochory (self-dispersal) processes such as gravity that can move seeds from A to B – for example by rolling down a hill.

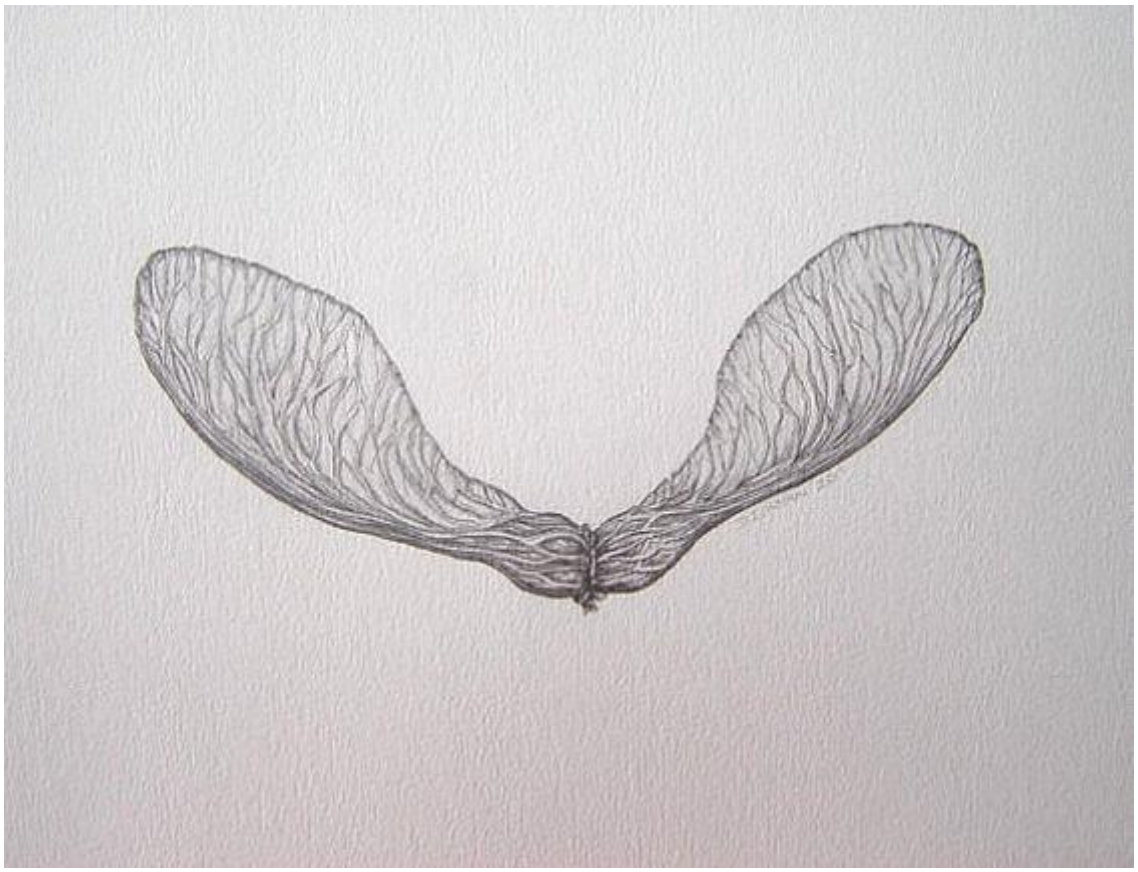


Figure 24: Sycamore Seed showing extended pericarps. Credit: Worksonpaperart, Etsy.com

§2.5 – The Woody Plant Root System

§2.51 – Functions of the Roots

The roots of a woody plant provide numerous different roles. Four of which are:

1. *Anchorage*. Woody plants are especially heavy and wide-spreading, so an extensive, mature and robust root system is required to support the above ground portion of the organism. It needs to not just support is own mass (static mass) but also the extra stresses placed upon it by other forces, such as the wind (dynamic mass). An extreme example of this is the colossal *Sequoiadendron giganteum*, which grows up to 85m and has a shallow root system that can span 30m in diameter and cover over 0.3ha with roots exceeding a foot wide[52].
2. *Nutrition*. Naturally roots primary goal is to absorb nutrients and water from the soil, often with the mutualistic help from microorganisms and fungi, to provide the organism with an energy source for photosynthesis and other biochemical processes. Root hairs are present in the majority of trees.
3. *Storage*. Another specialised structure within roots is the ability to store the end products of biochemical processes for use later – something which is of vital importance when entering a dormant period. This is primarily concentrated within the cortex, but in some species of non-woody plants, there are specialised structures such as tubers.
4. *Regeneration*. Some species of plants, when damaged or otherwise, can form new stems from the roots themselves which allow the proliferation of the organism even after what should have caused its death. An clear example of this is the tree colony *Pando* which covers 43ha and has been determined to be all part of one expansive system (Figure 25: Pando, all one organism.).

[52] *"Giant Sequoia", C. Phillip Weatherspoon, https://www.na.fs.fed.us/pubs/silvics_manual/Volume_1/sequoiadendron/giganteum.htm*



Figure 25: Pando, all one organism.

§2.52 – Root Forms and Shapes

There are many forms and shapes which roots takes. Regarding forms, the two most common root systems are fibrous systems and taproot systems.

In *Pinophyta spp.* And *Quercus spp.*, for example, a large taproot is often formed and maintained throughout the life of a plant, whereas in *Acer spp*. Taproots are rarely created. These types of roots are primarily used for a mixture of anchorage and food storage.

Many trees also form purely fibrous roots instead of a taproot system. Fibrous roots "are shallow, wide-spreading [and] numerous"[53], as seen with *Cocos nucifera* and *Fraxinus excelsior,* and serve to absorb nutrients and water, as well as providing anchorage.

Some trees, such as many of the above *Pinophyta spp.* which form taproot systems also can create a mixed, or dual, system. For example, should the taproot encounter a solid object then many trees with such systems will switch to a fibrous root system.

Lastly species such as those belonging to the genus *Larix* and *Betula* form what is known as a "heart root system", whereby the roots grow as angles to the trunk before curving back into the centre deeper in the soil – thus creating a heart shape when taken from a 2-dimentional perspective.

When it comes to the more basic shape of woody plant root systems there are two of interest to the arborist, especially when applying fertiliser or the like, and these are "extensive" and "intensive" root systems.

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[53] *Read About Root Development, Len Phillips, http://gibneyce.com/1-read-about-root-development.html*

Extensive root systems extend beyond the dripline of the given tree, although they are otherwise quite shallow, relatively speaking, when compared to intensive root systems which are compact and confined to within the tree's dripline. Extensive root systems are more common, with an example being *Quercus spp.*, while intensive root systems are more familiar with plants than trees, for instance, tomatoes form deep but compact roots.

§2.53 – Root Development Factors

Roots, like the rest of the tree, are living and thus react to environmental conditions when undergoing periods of growth. Four factors that contribute to the ultimate root distribution within the soil are:

1. Soil structure. Roots are naturally inclined to avoid high clay soils – where there is little oxygen, especially at depths – and highly sandy soils – where there is a dearth of water and nutrition due to excessive drainage and leeching. Rather roots will seek out the best of both worlds, where the soil's pore size is neither too big or too small.
2. Barriers. Roots that encounter barriers, whether natural – such as rocks – or manmade – such as plastics – will clearly have growth that is impaired in that given direction. This being said, if the barrier is not complete then roots have a tendency to find their way around them.
3. Fertilisers and herbicides. As the primary goal of roots is to absorb nutrients, alongside water, should roots encounter a cluster of nutrition, such as fertiliser, then they tend to distribute themselves to a greater degree around such a location. Likewise, should roots face herbicides then the roots will be impaired or killed, thus leading to "dead spots", or voids, within the soil where no roots are distributed.
4. The angle of growth. Roots typically demonstrate positive geotropism. For this reason, trees that are grown on slopes will often have their roots spread towards the bottom of the hill or otherwise. This is to say that roots will not tend to grow at a height greater than the base of their trunk. For a tree that is on a hill, this naturally leads to a higher density of roots at one side of the hill (Figure 26: Root distribution on a slope).

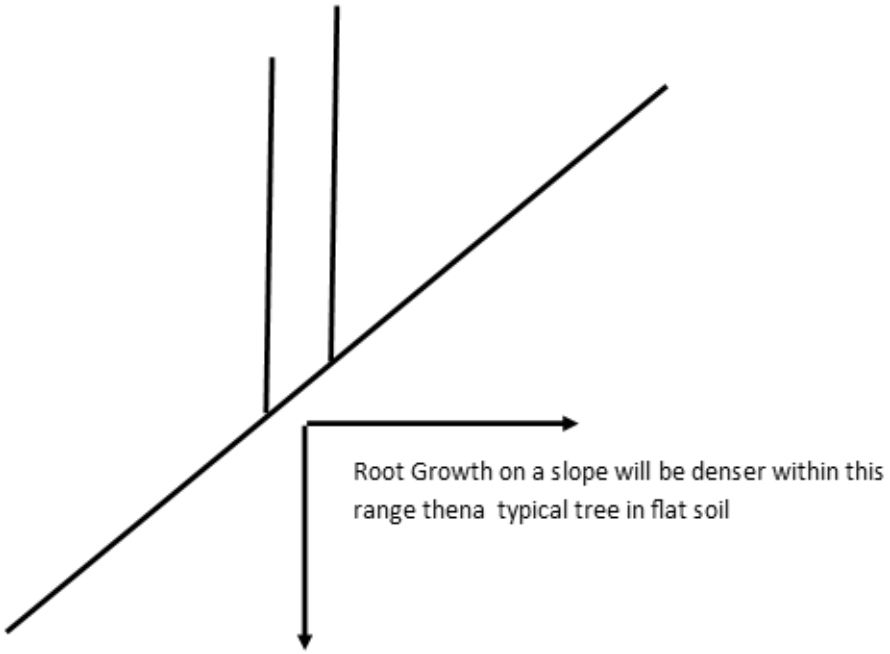


Figure 26: Root distribution on a slope

§2.54 – Root Anchorage

Tree anchorage is simply how a tree stabilises itself against dynamic stress (i.e. wind) and how a tree's roots support the canopy from all pressures, both dynamic and static. Two ways in which this is achieved is by osmotic pressure and the creation of vacuum spaces. When water is drawn up into the roots, this creates a suction zone around the root hairs which leads to a small volume of anchorage which is amplified by the sheer number of root hairs performing such. In conifers, this behaviour is generated by mycorrhiza.

Another way in which trees become anchored is by the growth of large, lateral woody roots which could almost be said to clench the soil and hold a tree in place. This is especially powerful in clay soils which are naturally dense and cohesively bonded to one another, but in sandy soils, such roots are relatively useless.

This all being said there are a few ways in which root anchorage can be damaged. The most obvious are by root rot or root damaging diseases, but besides this, there are two of interest to the arborist:

1. Herbicides causing root death. The application of herbicides, for whatever reason, can easily lead to the death of roots and the subsequent breakdown of the now dead material. This naturally weakens a tree's root anchorage system as the spread and density of such roots is reduced, leading to poor cohesion and suction pressure overall.
2. Pruning. Excessive root pruning, otherwise known as over-pruning, can easily result in a weak support structure. For example, if we were to prune all of the roots on one side of a tree then it would be obvious that gale coming from that given direction could easily topple the tree as there would be no roots to hold the organism in place. Although pruning is rarely going to be quite as dramatic, it nonetheless demonstrates how the loss of roots, or even just a few major lateral roots, can severely undermine the stability of a woody plant.

§2.55 – Shoot to Root Ratio

The shoot to root ratio is "the ratio of the weight of the roots to the weight of the top of a plant", which is typically 5 to 6 times greater[54]. It usually describes the rate at which photosynthates are used in comparison to primary nutrients, such as water and raw chemicals such as phosphorous and nitrogen. In general, the use of these two components is balanced, and should either one or the other become unbalanced then the health of the woody plant is jeopardised.

Although the precise ratio is typically tied to environmental condition, there are some broad statements that can be made. For example, during early growth the shoot to root ratio is generally low as the tree attempts to gather the raw materials for vegetative growth (as well as the production of enzymes and the like), whilst in more mature trees it is high (Figure 27: Shoot to Root Ratio), where the primary goal is sustainability which required more photosynthates then primary nutrients.

[54] "Root to Shoot Ratios", Richard W. Harris, Journal of Arboriculture (Jan 1992)

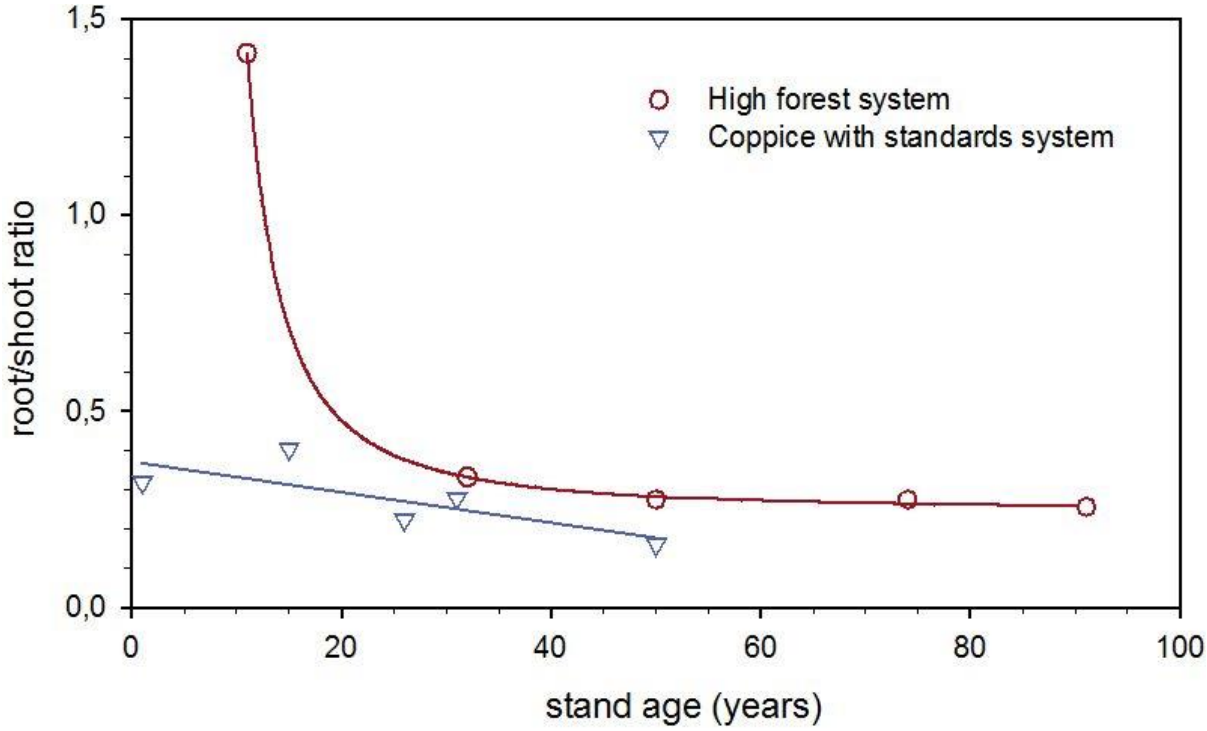


Figure 27: Shoot to Root Ratio[55]

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§2.6 – Tree Biomechanics

§2.61 – Definition of Biomechanics

Biomechanics can be described as the union between the biological sciences and the mathematic discipline of applied mechanics. Put simply it outlines the mechanics of living organisms, such as in our case trees, in regards to the forces applied upon them by nature or otherwise. An example of this is the roots response to crushing (as in soil compaction) or the stem, branches and trunk's response to gale force wind applying lateral forces – bending the trees. A few examples of biomechanical terms are described below.

§2.62 – Axiom of Uniform Stress

An axiom is a fundamental principle that although not proven is assumed to be true. In this case, the Axiom of Uniform Stress is the idea that trees are, for the most part, self-optimising and grow in such a way as to balance the compressive and tensile stresses throughout the organism. That is to say that, in general, there is uniform stress distributed throughout the tree. If there is an imbalance of pressure within the organism, then the tree adapts and 'fills in' the weak-spots by whichever means it chooses. One example of this is that of tension-wood and compression-wood, formed by angiosperms and gymnosperms respectively.

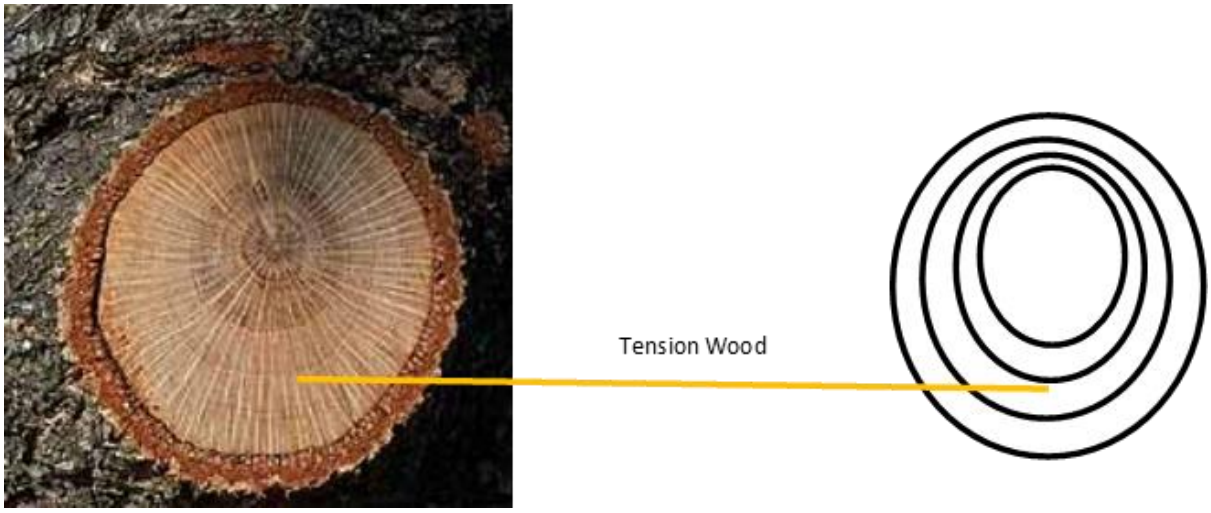


Figure 28: Tension wood in Quercus acuta

Although there are different mechanisms involved, both tension-wood and compression-wood are ultimately one and the same process. In angiosperms, such as in *Quercus acuta* as seen above (Figure 28: Tension wood in Quercus acuta), when they are subjected to tensile stress – such as bending during strong wind – new wood is formed at such a location to reduce the stress on the tree as a whole. This gives the tree's cross-section an unbalanced look, as seen above, and demonstrates the ability for angiosperms to react to shearing forces. The reason extra wood is formed is that tensile stresses pull apart and cause microfractures within the wood's structure, which are then filled in by the organism.

In gymnosperms, the same occurs, but along the side of compressive stresses. In this scenario, the cells are being crushed, so when new cells are formed instead of only just slightly widening and increasing the girth of the branch or trunk, it also increases the density of the wood itself (Figure 29: Severe Compression Wood in a Conifer). This is to say that more cells are crushed into a smaller area in order to support the tree.

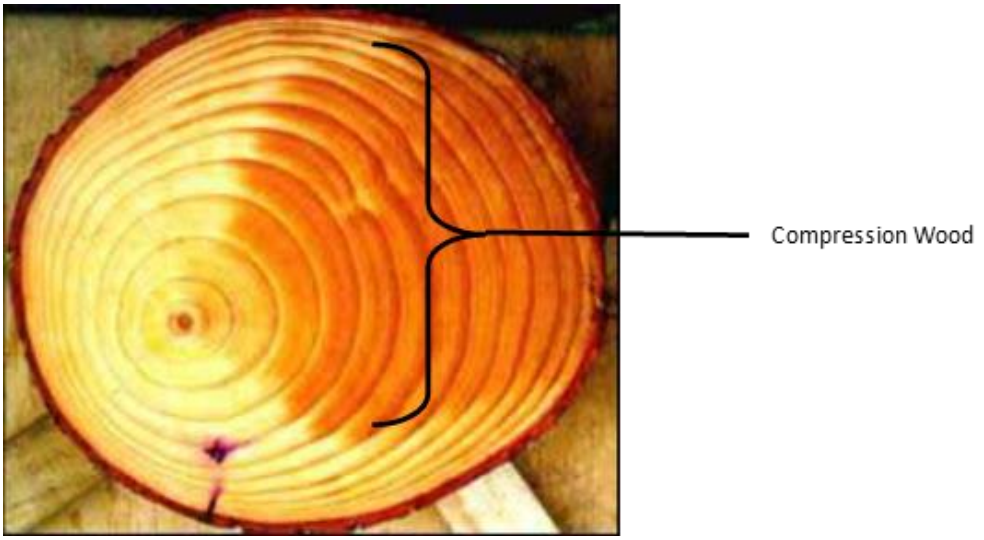


Figure 29: Severe Compression Wood in a Conifer

For a given bending or shearing stress, such as wind, compression-wood is formed on the *opposite* side of impact, while tension-wood is formed on the *same* side of impact (Figure 30: Tension and Compression Stress and Wood).

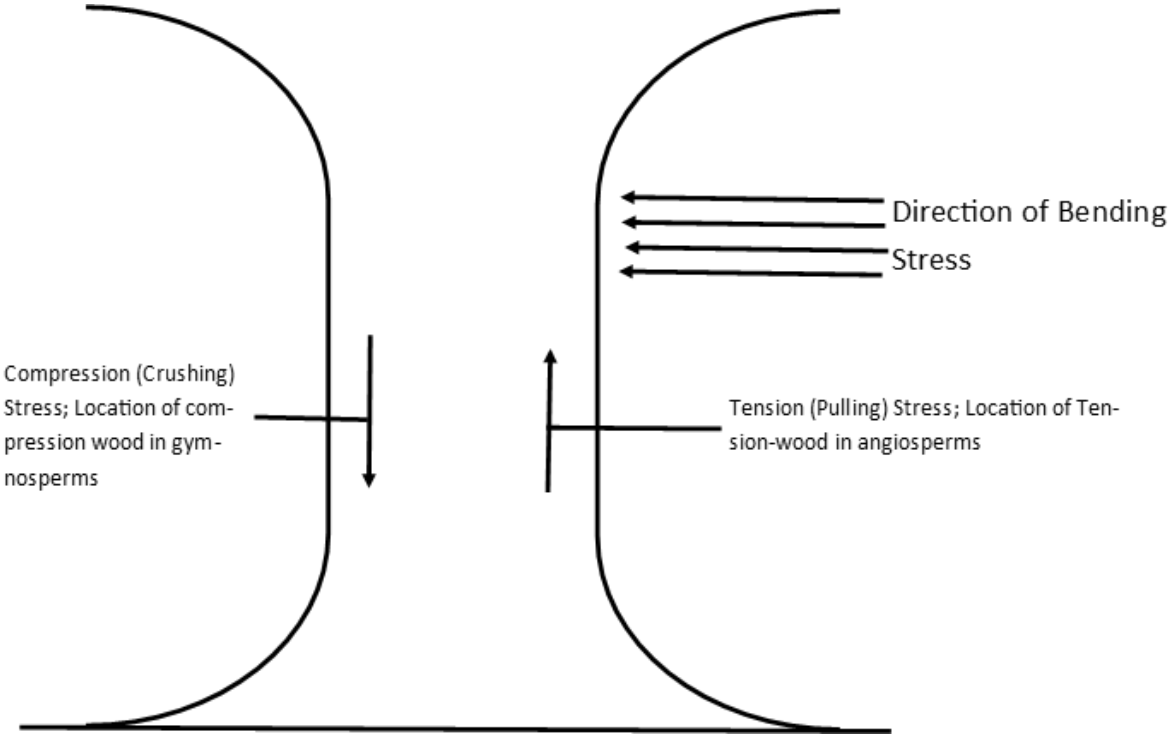


Figure 30: Tension and Compression Stress and Wood

§2.63 –Minimum Lever Arm

The minimum lever arm can be broadly described as the point at which gravity acts upon a lateral structure, such as a branch, and forces it to act much in the same way as a lever. In other words, for a *lone* branch attached to a trunk, the lever arm is slightly offset to the main stem and the centre of gravity could cause the organism to, over time, bend. To react to this stress, a tree lays down reaction wood, in the form of compression or tension wood, to 'bend' a tree upwards and back into shape - so that it's

centre of gravity is found in the main trunk, preferably at the centre (Figure 31: Leverage Point of a Branch)

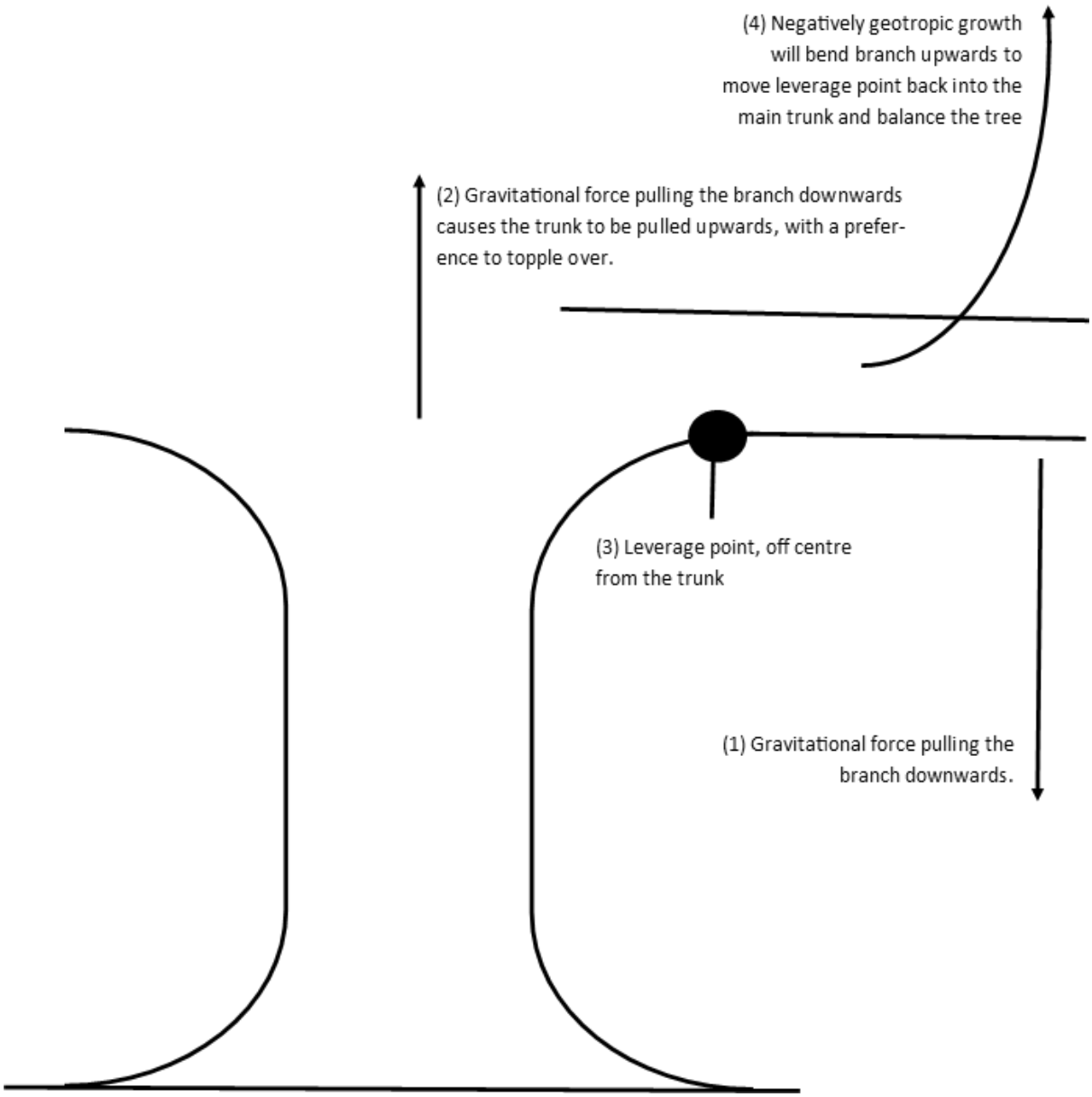


Figure 31: Leverage Point of a Branch

In other words: "Apical dominance and negative geotropism are balanced continuously to adjust the optimum angle between branch and stem"[56] – that is to say, that trees have a preference for upright growth, also known as negative geotropism, and will balance the load of the branches to ensure it doesn't topple. An example of this is given in Figure 32: The Crooked Forest (Krzywy Las) of Pine Trees in Poland – where tree bent in their infancy have formed reaction wood and re-centred themselves over time so that they are balanced. It's worth noting that in many cases there is a mixture of reaction wood and improved root anchorage balancing a tree. In the Crooked Forest example, it is, for instance,

[56] *"The mechanical self-optimisation of trees", C. Mattheck and I. Tesari, https://www.witpress.com/Secure/elibrary/papers/DN04/DN04020FU.pdf*

likely that the root system of the trees is more extensive on the side opposite to the bend, which consequently serves to "hold" the tree down.



Figure 32: The Crooked Forest (Krzywy Las) of Pine Trees in Poland

§2.64 – Hazard Beams

Hazard beams are essentially what they're described as: hazardous beams or branches. More specifically hazard beams are formed when the outward negatively geotropic growth of a branch is nonetheless pulled downwards by gravity. This severe application of opposing forces can eventually lead to the formation of a hazard beam and the eventual cracking and splitting of the branch (Figure 33: Split Branch, via ArbTalk.com).

Another way to describe this is that a hazard beam is "a curved woody stem, whose loading tends to bend it against the direction of curvature, has a tendency to split through the centre, having the effect of straightening the part"[57] – in other words, the compression force on the underside of the branch, caused by the pull of gravity at the end, and the tension force on the upper side, cause by the natural desire of wood to stay together, exceeds its limits and causes a rapid and potentially catastrophic split. This leads to a modified lever point and a rebalancing of forces. Another example is seen with Figure 34: Hazard Beam in a Willow Tree. The leading cause of hazard beams is "because of the low transverse

[57] *"Hazard Beam", Tree Terms Dictionary, http://www.treeterms.co.uk/definitions/hazard-beam*

tensile strength of wood"[58], that is to say, that the strength of wood across the grain is relatively small compared with the strength of wood running down the grain. This consequently leads to an increased risk of transverse failure. i.e. wood has a greater tendency to split rather than snap.



Figure 33: Split Branch, via ArbTalk.com

[58] *"Transverse stresses and modes of failure in tree branches and other beams", Roland Ennos et al., https://www.researchgate.net/publication/40696150_Transverse_stresses_and_modes_of_failure_in_tree_branches_and_other_beams*



Figure 34: Hazard Beam in a Willow Tree[59]

§2.65– Bulges

Bulges in trees are just that, bulges. Specifically, they indicate "a tree's reaction to a defect such as hollow decayed spot or a crack, or reaction to a pruning cut"[60], as well as pathogenic infection. They demonstrate the ability for a tree to ramp up the production of new wood to fill in or repair damages that could kill the organism. For example in the below image (Figure 35: A bulge in the base of a tree, via University of California) we can reasonably assume that the bulge is the result of cracks or splits, however large or small, caused by tensile forces. The reason for this is that the tree is bending away from the bulge, which would seem to indicate that there is tension stress on the left side (relative to the image). This may be assumed to cause microfractures or otherwise which would then be repaired with reaction wood to stabilise the structure and avoid catastrophic failure. If we were to take a cross-section of the base, then it may appear that there is a great deal of tension-wood where the bulge is located.

[59] *https://arboriculture.wordpress.com/2016/02/29/a-hazard-beam-on-a-willow-salix-sp/comment-page-1/*

[60] *"Trunk Bulges", Landscape Plants, http://hort.ifas.ufl.edu/woody/trunk-bulges.shtml*



Figure 35: A bulge in the base of a tree, via University of California

§2.7 – Defence Mechanisms Used by Woody Plants

§2.71 – Overview of the Purpose of Physical Defence Mechanisms

Physical defence mechanisms are designed to, or have evolved to, help trees, and other plants, to resist attack by hazardous or hostile forces, such as animals and pathogenic microorganisms. In essence, the concept of physical measures to resist ill health describes the ability for a woody plant to combat and prevent the appearance of poor health.

§2.72 – Spines, Thorns, Prickles and Trichomes (Hairs)

Spine, thorns and prickles, collectively known as spinose structures, are in appearance similar – and indeed often confused - although they each have a slightly specialised function that sets them apart, as we will discuss. Their primary role is to deter herbivores or omnivores from grazing and damaging or destroying the organism.

Spines are modified stipules, or leaves, that commonly taper to a sharp point. They are typically hard and ridged as in the case of cactus, such as that seen in Figure 36: Ferocactus echidne[61]. Some, however, can be flattened and hairy, containing countless smaller spines that detach and embed themselves in the skin or mouth of the praying animal – in which case they are known as glochids.

[61] *Anderson, Edward F. (2001), The Cactus Family*



Figure 36: Ferocactus echidne

Thorns are sharp outgrowths from the stem, and in particular of the cortex and epidermis that "may or may not be branched, they may or may not have leaves, and they may or may not arise from a bud"[62]. They are chiefly derived from shoots. A typical example of this comes from native Common Hawthorn, *Crataegus monogyna (*Figure 37: Hawthorn Thorns), where the thorns take the appearance (and feel, as I have discovered) of modified, sharp branches. This is unlike spines as they are not simply specialised leaves and are incapable, generally, of any form of photosynthesis.

[62] "Spine (Botany)", Revolvy, https://www.revolvy.com/main/index.php?s=Spine%20(botany)&item_type=topic



Figure 37: Hawthorn Thorns

Prickles "are derived from epidermis tissue"[63]. It could be said that, simply, a sharp outgrowth from the stem or otherwise of a plant is a prickle if it is neither a modified leaf nor a modified shoot. The typical example of this is the "thorns" of a rose bush, *Rosa spp*. As we can clearly see from the below diagram (Figure 39: Rosa Stem Showing Prickles) the "thorns" are obviously not modified stems or twigs, and do not take on the appearance typical of leaves. For this reason, they are *technically* prickles, although in common speech and language they are nonetheless referred to as thorns.

Lastly trichrome, or hairs, are tiny specialised structures that often have a secondary purpose when compared to just prickles. They "can also possess insect-trapping barbs, or sticky secretions, such as those seen with the carnivorous sundew plant (*Drosera*)"[64] or the mint derived from *Lamiaceae*. One key difference between hairs and prickles is that hairs are outgrowths of the epidermis *only*, whereas prickles can involve lower layers such as the cortex[65].

[63] "Thorns, Spines and Prickles", Revolvy, https://www.revolvy.com/topic/Thorns,%20spines,%20and%20prickles&item_type=topic

[64] "External Hairs, Trichomes, spines and thorns", RHS Botany for Gardeners, page 210

[65] "Trichome", Wikipedia, https://en.wikipedia.org/wiki/Trichome



Figure 38: /Drosera capensi trichomes (hairs) showing a trapped insect

§2.73 – Bark Adaptions

The most obvious purpose of bark is to resist mechanical and insect damage. Being hard, strong, inedible and thick it takes lots of effort for an organism to penetrate the otherwise dead layer of cork and reach the living material such as the cork cambium or secondary phloem. This being said there are a few adaptions that trees have evolved to combat ill health when the bark is damaged, penetrated or split, for whatever reason. One way is by compartmentalising the wound. Another is the long-term replacement of cork by the phelloderm which seals the entry root with a distinctive callous. (Figure 41: Callous formed around a wound). Lastly, some trees can produce chemical responses which serve to attempt to poison or inhibit an attack from a living organism. I shall discuss some of these in detail later but for now it worth using an example.



Figure 39: Rosa Stem Showing Prickles

The Mountain Pine Beetle, *Dendroctonus ponderosae (*Figure 40 Adult Mountain Pine Beetle*),* is a particularly damaging pest in the United States and attacks mostly pine trees. Typically when infested pine beetles would encounter resin filled ducts, which slows their growth, and would discover that the

surrounding tissue would die – leading to unfavourable circumstances for the beetle. However, the Mountain Pine Beetle is frequently a host for the Blue-Stain Fungus, *Grosmannia clavigera*, which infects the very resin ducts designed to combat the beetle. The lack of resin production and nutrient translocation within the tree allows Mountain Pine Beetle larva to flourish[66] in the absence of the tree's defenses. This symbiotic relationship has led to whole forests being devastated by the bug.



Figure 40 Adult Mountain Pine Beetle

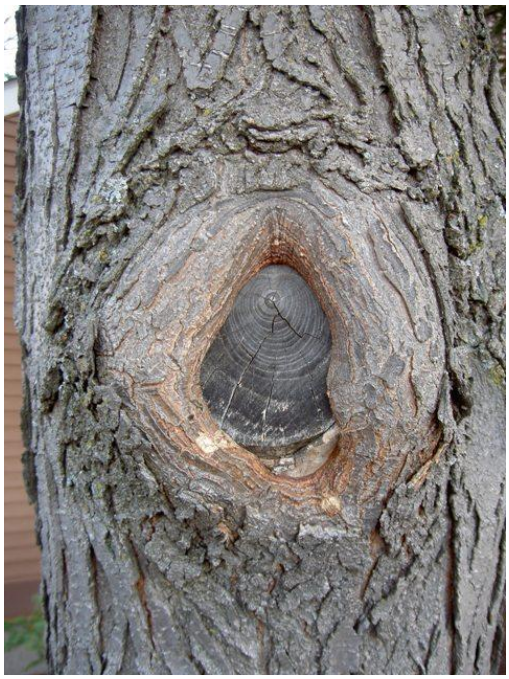


Figure 41: Callous formed around a wound

§2.74 – Leaf Adaptions

Like bark, there are many means by which leaves have adapted to resist attack. The most basic is the formation of an abscission layer at the base of the petiole which allows trees, and most plants, to abscise infected or otherwise unhealthy leaves. This could be considered a second line of defence for some plants.

The first line can be seen in plants such as Holly (*Ilex spp*) including the native *Ilex aquifolium* which has evolved slippery, glossy and spiny leaves (Figure 42: Ilex aquifolium leaf) which deter grazing from herbivores, although many ruminants have evolved the ability to feed upon them regardless.

[66] "Blue-stain fungi in xylem of lodgepole pine", R. G. Ballard and M. A. Walsh, http://www.usu.edu/beetle/documents2/1982Ballard%20etal_Blue%20Stain%20Fungi%20in%20Xylem%20of%20LPP.pdf



Figure 42: Ilex aquifolium leaf

Other plants have even evolved toxic leaves that poison insects and animals feeding upon them. A good example of this is many of the plants in the Nightshade family (*Solanaceae spp.*) and in particular plants of the *Nicotiana* genus which have evolved potent insecticidal alkaloids to resist attack. Many of these types of defences, however, are not completely resistant to pathological agents as can be seen with the occurrence of the Tobacco Mosaic Virus in *Nicotinana spp.*.

Lastly, a few plants have evolved *Raphides*, "needle-shaped crystals of calcium oxalate or calcium carbonate that make ingestion painful"[67].

§2.75 – Terpenes, Phenolics and Cyanide

Besides purely physical means of protection, plants and trees have, over the years, evolved chemical mechanisms by which to deter or kill predators. A well-known example of this is cyanide compounds, typically glucosides, that are found in the seeds of various plants within the *Rosaceae* family, most notably those within the genus *Malus* (Apple) and *Palus* (The Stone Fruits, including Apricots and Plums). Given the notable toxicity of cyanide and it's bitter taste, one potential reason for its occurrence is to deter herbivorous predators. That being said, many animals – including birds and some apes – have co-evolved a resistance to the toxin, even if only slightly.

Phenolic are a broad range of chemical compounds that include a hydroxyl group (OH), whereas Terpenes are built up from Isoprene molecules (C_5H_8). Both are found in a range of plants, insects and animals and, relevant to us, trees – both conifers and broadleaves – where they are typically found within resin ducts, as in the case of conifers, or within the vacuoles of parenchyma cells.

As opposed to cyanide, which primarily targets large animals, terpenes primary role is to kill and disrupt insect attack – although they do, it is worth mentioning, serve other biological functions. One notable example is *pinene*, a terpene found in the wood of pine trees. Evidence has shown it to be an incredibly potent insecticide[68]. Phenols on the other hand are geared towards repelling herbivores, but not by simply poisoning. Rather, they serve to attract insects with their aroma, which go onto discourage or

[67] "Botany for Gardeners", RHS, Page 210

[68] "Repellent activity of essential oils: A review", Luz Stella Nerio Quintana et al

attack their predators. Furthermore, phenols require energy to break down and excrete[69], which thus reduces the nutritional value of the food. Lastly, phenols have antiseptic properties which help combat pathogenic invasion.

§2.76 – Compartmentalisation of Decay in Trees

Compartmentalisation of decay in trees, also known as CODIT, describes the process by which woody plants can limit the spread of pathogenic infection – decay – by "compartmentalising" damaged wood and virtually shutting it off from the rest of the organism. It does this by limiting the four different means by which fungi and bacteria can move about the wood by constructing four walls (Figure 43: CODIT in Peach, TreeDictionary.com):

1. The first wall is vertical and runs the length of the branch or trunk. One of the most obvious routes for pathogens to take is up and down xylem, phloem and tracheids. Trees thus typically block these routes by producing chemicals to plug the channels – for example in gymnosperms resin is the common substance used.
2. The second wall is inwards; annual growth rings, and in particular, latewood which contains high volumes of resistant lignin serves as a second barrier and prevents the spread of a disease towards the centre of the tree and to the heartwood.
3. The third wall is lateral and primary aim is to avoid side to side decay – after all if both wall 1 and 2 are successful, but wall 3 fails, then a major weak point occurs in the wood – a period where the whole of a season's annual growth above and below a given point has decayed. .
4. The last wall is also lateral but on a long-term time scale. Essentially as a tree continues to grow, it will consume the wound and entomb it in new wood – thus completely sealing it off and reducing the ability for pathogens to survive. For small wounds, this can take as little as one growing season, but for large wounds, it may take decades.

[69] "Tannins and Phenols", Lindsay VanSomeren, https://lvscaribouresearch.wordpress.com/about/tannins-and-phenols/

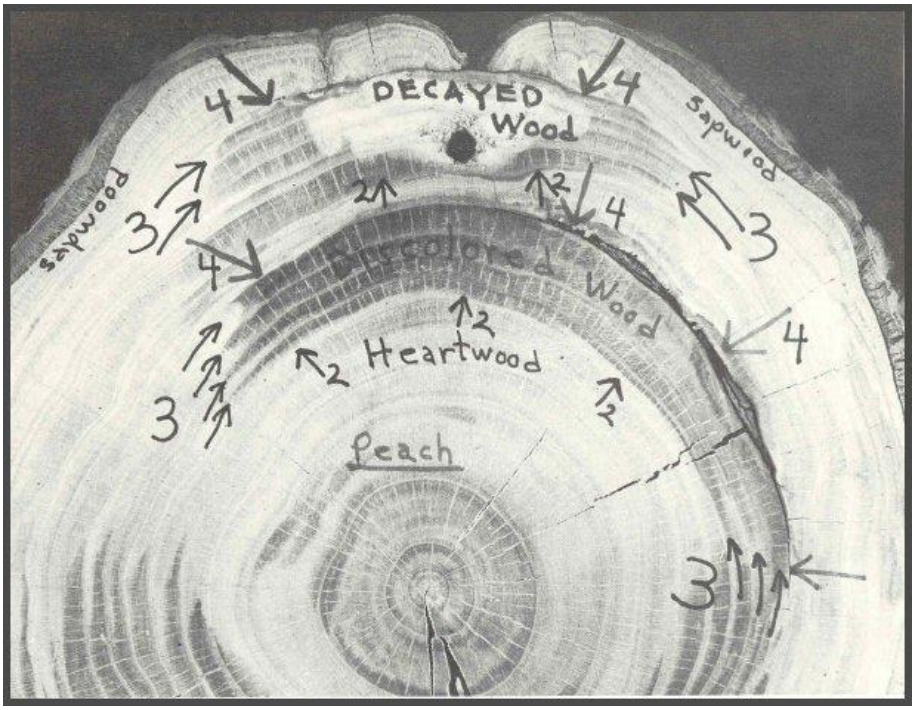


Figure 43: CODIT in Peach, TreeDictionary.com

These four walls can broadly be broken down into two distinct zones: the reaction zone and a barrier zone. The reaction zone is just that: the zone where the organism swiftly responds to damage or pathogenic infection. It is walls 1-3 which form this zone, and it is the area which can be modified chemically or physically by the host to resist decay.

The barrier zone, on the other hand, is wall 4. It is how a tree forms a protective barrier against potential sources of infection. To use an example, imagine one has a cut on their hand. The human body has many reactions zones and walls to prevent infection: Inflammation, increased white blood cell activity, histamine response, etc., but it is not until a barrier zone – a scab – has been formed that the risk of a new infection is completely reduced (and the internal walls having been successful!). Likewise, in trees it is not until a barrier zone has been formed that the risk of infection is eliminated, assuming the reaction zones have been a success.

§2.77 – Woundwood

A callus, in botany, is the "tissue that forms over a wounded or cut plant surface" and are, more specifically, a tightly bundled, homogenous and disorganised mass of parenchyma tissue. Being meristematic calluses can form a variety of different specialised structures – such as new branches or roots – but as soon as the cells differentiate and become lignified they become part of what is known as woundwood[70].

One means by which this process develops comes from the internal pressure placed upon each callus' individual parenchyma cell. Typically parenchyma cells are held in place, and stopped from dividing, by the pressure exerted upon them by surrounding tissue. When injured, however, this pressure is released, and they start dividing until there is so many of them that they exert pressure on themselves.

[70] "Callus becomes Woundwood", Tree Dictionary, http://www.treedictionary.com/DICT2003/boonites/callus/index.html

It is at that point that the cells begin to differentiate and form more organised structures[71] (Figure 44: Closed callus showing woundwood and new bark growing atop it. Via forums2.gardenweb.com).



Figure 44: Closed callus showing woundwood and new bark growing atop it. Via forums2.gardenweb.com

[71] "Woundwood and Callous, The Tree Dictionary, http://www.treedictionary.com/DICT2003/HTMLFILES/woundwood-1.html

§2.8 – Ill Health in Woody Plants

§2.81 – Pest, Diseases and Disorders

The difference between a pest and a disease is subtle but distinct. Put simply; a pest is specifically any insect or animal organism that causes damage to a woody tree, while a disease is any set of symptoms that indicates ill health – typically by microorganisms such as bacteria. A disorder is any set of symptoms that is a deviation away from the norm but not necessarily caused by a pathogen or pest. For example, nutrient deficiency is a disorder. A couple of examples showing the difference follows using holly – *Ilex aquifolium* – as a host.

Pest	*Phytomyza ilicis* (Holly leaf miner)		Symptoms: • Chlorosis • Shallow burrows underneath surface of leaf • Centralised yellow/brown blotches[72]
Disease	*Phytophthora ilicis* (Holly leaf blight)		Symptoms: • Black and Red blotches • Leaf abscission • Blackened stems[73]
Disorder	Scorch		Symptoms: • Venial chlorosis • Browning of leafs • Leaf abscission • Wilting

§2.82 – Laetiporus sulphurous Colonization Strategy and Implications

Laetiporus sulphurous, or Sulphur Polypore, is a basidiomycete of the polyporales order and, like most polypores, are a species of bracket fungus which feeds on the wood of trees. In particular *L. sulphurous* causes a type of brown rot, and although it typically only feeds on dead wood such as heartwood – making it a saprophyte – it nonetheless can feed on living sapwood, thus, in reality, it is a facultative parasite. It prefers *Quercus spp.* (Oak) and has implications for the species regarding structural stability and it's eventual decomposition. In the latter scenario, the species has a large amount of effect on the eventual breakdown of dead wood, although if the tree is living, then this could result in impaired structural stability as the heartwood and bark is destroyed. In living wood, *L. sulphuirous* can damage vascular structures, weaken sapwood – allowing an entry route for more destructive parasites – and invoke chemical responses that lead to effects such as CODIT.

[72] RHS.org.uk

[73] RHS.org.uk

Regarding the fungus life cycle, the fruiting bodies of the fungus, which are a distinctive flattened yellow disk often occurring in shelves, produce haploid (containing half a set of chromosomes) spores through meiosis. These are released and carried by the wind to another host where there is a suitable entry route, such as an injury, crack or another form of rot (Figure 45: Laetiporus sulphurous fruiting bodies in a trunk opening). At this point, they develop hyphae and eventually mycelium[74] and begin feeding. It is at this stage that they must wait until they encounter another spore, containing the other half of the genetic information they require. They then fuse and produce a diploid individual that is capable of forming fruits and continuing the cycle.[75]



Figure 45: Laetiporus sulphurous fruiting bodies in a trunk opening, via YouTube

§2.83 – Brown Rot vs. White Rot

There are a few different types of rot which are caused by a multitude of different diseases each, but two of the most prevalent are brown rot and white rot, both of which are caused by Basidiomycetes.

One of the most distinctive features distinguishing both types of decay is the structure that the wood takes on following infestation. With white rot, some light-coloured cellulose remains while dark coloured lignin is destroyed, which leads to a fibrous structure that appears bleached. An example of white rot is *Armillaria mellea* (Honey Fungus) which causes root rot.

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[74] "Pale Chicken of the Woods", Missouri Department for Conservation, https://nature.mdc.mo.gov/discover-nature/field-guide/pale-chicken-woods

[75] "Chicken of the Woods", University of Virginia, http://www.mlbs.virginia.edu/organism/laetiporus_sulphureus

In brown rot, cellulose is destroyed while then oxidised lignin remains. This leads to shrinkage which then results in the wood cracking into cuboid structures (Figure 46: Brown rot (left) vs white rot (right)). An example of brown rot is the aforementioned *Laetiporous sulphurous* (Sulphur Polypore).

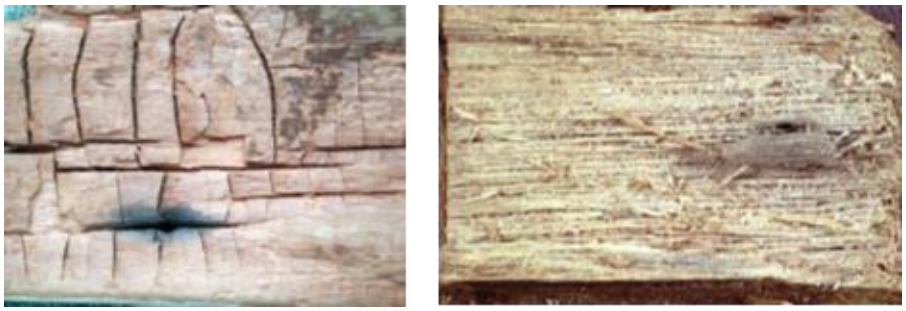


Figure 46: Brown rot (left) vs white rot (right)

Given all this, the term "woody plant rot" can simply be taken to mean any organism, pathogen or fungus that lead to the breakdown of cellular structures within a tree and which ultimately results in damage, such reduced structural integrity, or death to the organism – if still alive.

§2.84 – Armillaria mellea Implications, Prevention and Control

The previously mentioned *Armillaria mellea* (Honey Fungus, Figure 47: Severe Honey Fungus Infection) has a broad range of consequences for the living trees of a huge number of genera. It is a facultative saprobe, meaning that it prefers parasitic activity, but can just as well survive on dead matter. Indeed, the damage caused by *A. mellea* is so widespread that by the time fruiting bodies appear death almost always imminent.



Figure 47: Severe Honey Fungus Infection

Regarding symptoms and signs of an *A. mellea* infestation they include: chlorosis, stunted leaves, cracked bark, excessive fruiting, rotten roots and extensive mycelium sheets underneath the bark of the bottom meter of the tree[76]. The implications are obvious: death.

Regarding control, there is little else to do except to destroy the afflicted plants. Since *A. mellea* spreads through rhizomorphs – tentacle-like outgrowths within the soil that seek out roots – as opposed to spores, all suspected infected topsoil should be removed and replaced with new uncontaminated soil. Furthermore, to prevent adjacent soil contaminating the new soil, a physical barrier – such as a plastic sheet – should be installed at the walls of the area[77]. There is, unfortunately, no chemical control for the parasite that is guaranteed to work, although fumigation with "chloropicrin, methyl bromide, and carbon disulphide, can reduce the infection level"[78]. Lastly, pre-treatment with ammonium sulphamate can encourage the growth of positive bacteria and fungus which can outcompete *A. mellea*[79]. Culturally, choosing resistant tree species, such as *Taxus spp.* (Yew) is advised in contaminated areas.

[76] "Honey Fungus", RHS. https://www.rhs.org.uk/advice/profile?pid=180

[77]"How to spot Honey Fungus and what to do about it", The Express, http://www.express.co.uk/life-style/garden/443723/How-to-spot-honey-fungus-and-what-to-do-about-it

[78] "Armillaria", US Department for Agriculture, https://www.na.fs.fed.us/spfo/pubs/fidls/armillaria/armillaria.htm

[79] "Honey Fungus", Tree Maintenance, http://www.treemaintenance.co.uk/honey-fungus/

§ 3

The Supply, Planting and Aftercare of Woody Plants

§3.1 – The Value of Woody Plants in the Environment

Trees, in general, have a wide array of benefits to the natural and urban environment. Whether this is by contributing to the look and feel of the surrounding environment, or something more objective such as noise or pollution reduction, every species can have a use. Below I have described ten such uses for trees, and also provided an example of each with a short description of why I have chosen such for the given use.

CO_2 Reduction

For this use, I decided that the best means of CO_2 reduction come in the form of carbon sequestering. Although this is best achieved via rapid growth, I also felt that the individual tree must be able to build a collective forest. For example, *Sequoiadendron giganteum* is quick growing and large, but it would struggle to create forests here in the UK.

For this reason, I decided on the coniferous evergreen spruce, *Picea abies*, which has been used in this country for afforestation (Figure 48: Picea abies forest demonstrating its). It is rapid growing, at around 1m per year, and can thus sequester a large volume of CO_2. Furthermore, the nature of *P. abies* and other *Picea* spp. – in that, they grow bolt upright and tall – makes it ideal for use in softwood timber which will naturally lead to the long-term storage of carbon for as long as the end product is not burned.

Although on a global scale afforestation or even reforestation could not hope to sequester all the CO_2 that is released worldwide, on a more local level the construction of forests and woodlands can help to reduce the pollution within towns and villages.



Figure 48: Picea abies forest demonstrating its widespread proliferation

Windbreak

In areas of high wind, or on open plains, a natural windbreak can be precious regarding protecting houses and gardens, amongst other things such as pedestrians and cyclists, from the full force of nature. We know from experiments that a wind break from a tree is most effective for a distance ten times of the height of the given tree, and is partially effective for up to 30 times the height.



Figure 49: Cupressus × leylandii by Louis Contino

For this reason, it can be evident that the most effective windbreaks – if that is all that one is looking for – come from the tallest trees. Not only this, but the given trees need to be quite bushy and dense to stop the wind simply rushing through it – perhaps actually increasing in speed as it is funnelled through.

One of the most useful and common windbreaks is the infamous Leyland cypress - *Cupressus × leylandii*. As we can see from the image to the left (Figure 49: Cupressus × leylandii by Louis Contino) although the tree itself is thin, it is also quite compact. It would be resistant to bending or deforming and, most importantly, has branches all the way down to nearly the base. This inhibits the natural inclination for the wind to be pushed under at high pressures and speed. Given that these trees can reach a height of 15m or more, it can be said that a row of Leyland Cypress could potentially provide protection for up to 150m and partial protection for up to 450m. A single row (Figure 50: Leyland Cypress Windbreak) could help shelter an entire neighbourhood. Having said this, a length to height ratio of 12:1 is required for optimum protection in order to prevent the wind simply flowing around the trees. Therefore it is more practical from a horticultural perspective to seek to protect houses, garden and paths on a case by case basis. A 2m high Leyland hedge could protect a modest garden, for example.



Figure 50: Leyland Cypress Windbreak

Privacy

One obvious practical and oftentimes visual use for woody plants is for privacy. Indeed, most hedges act as both windbreak and shields against prying eyes. There are a lot of factors that go into choosing the right tree for producing a hedge, but some factors that need to be considered are form, manageability, bushiness, susceptibility to disease, colour, texture, and so on.



Figure 51: Taxus baccata foliage

In day to day life most hedges are conifers, although smaller evergreen varieties do commonly exist. For many a hedge should be unassuming, neat, tidy, soft, and shouldn't detract or distract from the rest of the garden. For this I have chosen the "King of Hedges", *Taxus baccata*.

This species has dark green, glossy and soft foliage that forms dense cluster (Figure 51: Taxus baccata foliage) which block out even the most determined light. The tree itself grows at a moderate pace and so is neither unwieldy nor difficult to maintain, nor slow to establish. When grown in close proximity to each other they interweave beautifully and have a formal appearance– especially when managed well. Since their leaves are small and unassuming, when they come together en masse they produce a gentle, modest texture that doesn't insult the eye, and which forms a calm backdrop to perhaps a colourful garden. The berries themselves are small and do not themselves spoil the scene, although they can be poisonous!



Figure 52: Taxus baccata hedge

Shelter

In cities and towns across the world trees are used as shelter from the elements. Found along footpaths and roads, many woody plants serve a multifaceted purpose: they provide shelter from the rain and they contribute to the visual appeal of the surrounding area.

When it comes to shelter alone one of the perhaps greatest assets for the tree is the spread of its crown and the density of the foliage. Since many conifers have relatively thin leaves and stubby branches, broadleaf trees are typically preferred. Furthermore, another consideration is the height from the ground that the tree achieves at maturity – a dense, low hanging, bushy tree like the above *Taxus baccata* would be difficult to walk under, for example. Lastly from an engineering perspective the tree should preferably be easy to manage at maturity, and should be long lived. Having to replace a tree every decade in a highly-urbanized area would come at a great expense, for instance.

In a semi-urban, private or rural setting trees such as Oak (*Quercus* spp.) may be suitable for this usage, but in an urban setting such trees are *too* wide spreading and unwieldy – you might struggle to fit in a huge mature oak in between two large buildings for instance, and the trunk alone may consume most of a footpath. For this reason, smaller more compact trees such as *Plantanus x hispanica* (London Plane) may be preferred. This tree has a moderately sized bushy crown (Figure 53: Plantanus x hispanica's) which starts some way up the tree. As seen from the image the leaves are large and could easily deflect rain. It has a small to medium sized trunk to leave room for amenities such as roads and footpaths. It is pollution resistant, long lived and easy to manage once mature. Lastly it is attractive and unassuming and easily complements and brightens even the dreariest roads. Most famously it is used within London on popular roads such as the Mall and Birdcage Walk whereby it shelters and shades footpaths.



Figure 53: Plantanus x hispanica's dense crown

Noise Reduction

In modern life besides there being a vast quantity of light and gaseous pollution there is also an overabundance of noise pollution. Whether it be cars or trains or people there is often scarcely a moments peace. For those who desire a quieter home or garden, trees can be a valuable asset in the fight against noise. Although ultimately a wall provides the best protection they can be visually unappealing. For a more natural look, bushy, low branching plants are best. Unlike previously discussed hedges, such as those made for shade or privacy, noise reduction is best



Figure 54: I. aquifolium's dense foliage

achieved with non-coniferous evergreen or marcesent trees[80].

A popular shrub that can be used for this purpose is holly, *Ilex aquifolium*. With growth starting low to the ground, and with thick, dense, heavy foliage (Figure 54: I. aquifolium's dense foliage) and wide branches it is ideal for soaking up excess noise. However, it can be difficult to manage and in some cases dangerous due to its modified spiny leaves.

One benefit of *I. aquifolium*, though, is that it fits the stereotypical hedge-like form and style, especially from a distance (Figure 55: Holly Hedge). Because of this, and much like *Taxus baccata* and co, it is unassuming and blends in easily to the surrounding environment and garden – whilst still providing a good degree of soundproofing. It may also, as a side note, protect a garden from pests given its spikey nature.



Figure 55: Holly Hedge

Centre Piece and Beautification

Some trees make marvellous specimens when sat on their own, and can serve to create a stunning focal point to an otherwise standard or dreary scene. For this use a special or unusual tree is best used – one which can stand on its own and add a great deal of visual appeal to the given area.

[80]"Noise Blocking Plants", GardeningKnowHow.com, https://www.gardeningknowhow.com/special/spaces/noise-reduction-plants.htm



Figure 56: Liriodendron tulipifera in a park.

For this use, there are many considerations. For example, would one prefer a colourful tree, or one which impresses with its sheer size – or perhaps both. Does the tree need to have an extraordinary odour? Will it serve any secondary purpose, such as providing shelter for livestock? How much space is available? What *look* is one going for? – i.e. rustic (Then maybe *Quercus* spp.), oriental (Thus Japanese Maple), sheer intimidating size (Possibly *Sequoiadendron giganteum*) and so on. Does leaf shape matter? And so on. Then there are always the obvious considerations of maintenance and so on – for example is the tree going to be highly managed or left to grow in its natural shape?

One tree I would like to highlight is *Liriodendron tulipifera*, also known as a Tulip Tree. These trees can oftentimes stand alone, and hold their own, or they may be planted in the company of others within a park-like setting. They are large and tremendously bulky trees, reaching up to 35m in height, with a full-bodied form and a large round crown. Their leaves are a light shade of green, and the blossom can exude hints of yellow when in season. Although personally it doesn't hold a particularly unique character, I find the shape, form and texture to be warm and cosy and typical of parkland area (Figure 56: Liriodendron tulipifera in a park.) and something which demonstrates the sheer magnificence of some trees.

Fruit

Of course, besides all the above visual benefits, trees can also contribute economically to society. One of the most obvious means by which woody plants can generate money, if you will, is by producing fruit or nuts to go on to be used somehow. When it comes to fruit alone there are many serious considerations that must be taken into account before one embarks on the long-term process of growing fruit trees in itself – after all planting a tree that may take half a decade to fruit cannot be taken lightly, else a time-costly mistake will arise.

Such considerations include nutritional value – in the case of fruits that are to be eaten raw or cooked – disease resistance, taste, texture, rarity (rarer crops are more valuable), overall yield, time-to-fruit, initial

down payments, general yearly return, required maintenance, self-pollinating or sterile, and so on. As you can see there are numerous things which must be taken into account, but unlike what we have discussed thus far the actual form, shape and visual appeal of a fruit tree is irrelevant – an ugly tree can produce lovely fruit, and vice versa!

One of the first things that comes to mind when we speak of fruit is *apples*. These all come from *Malus* spp. One which I'll highlight is a Crab apple, *Malus* 'John Downie'. These produce sour fruit that are quite unlike the pure sweet apples we are accustomed to in the shops. From an economical perspective, these are often sold as is and utilized in recipes or eaten alone.

When it comes to its values, there are many. Since John Downie apples are a cultivar, they have been breed with disease resistance in mind[81]. They crop within some three years of planting, with the best yields coming after 4-5 years[82]. They have a high yield in themselves, and require only the bare minimum maintenance. They are self-fertile and continue to produce returns year after year – with the average mature tree producing 22kg of apples a year[83]. Once processed and cooked or made into secondary products they can create a fair deal of wealth. Lastly, on top of all this, John Downie Apples are also fairly ornamental so the best of both worlds is achieved.



Figure 57: Fruiting Malus "John Downie"

[81] "Sugar and Spice", The Telegraph, http://www.telegraph.co.uk/gardening/3335132/Sugar-and-spice.html

[82] "Stages of Apple Tree Growth", Stark Bros, https://www.starkbros.com/growing-guide/article/stages-of-apple-tree-growth

[83] "Apple Crab tree – John Downie", Suttons, http://www.suttons.co.uk/Gardening/Fruit/Fruit+Trees/All+Fruit+Trees/Apple+Crab+Tree+-+John+Downie_205374.htm#CMRTabs|CMRTabs2

Framing

For many, in both cities and rural areas, houses standing alone can be both bland and uninspiring. From a distance a brutalist tower block, or a huge stone mansion, can be greatly improved and given a sense of scale with the introduction of trees to frame the buildings. Furthermore, in crowded city streets which can invoke a sense of claustrophobia, trees can help make the area feel bigger, more refreshing and ultimately less imposing.

For this use, there are a few features that may be looked for. One of the most obvious is simply the size of the tree itself, but also the shape of its crown and the density of its foliage. For example, on a long road leading up to a large country home tall, slender trees would be preferable to invoke a sense of scale – especially if they are *shorter* than the house itself! Yet, at the same time, one would probably prefer trees whose foliage is light so as not to construct "walls" that can make the site feel smaller then it perhaps is. For this reason I would avoid conifers such as the Norway or Sitka Spruce (*Picea* spp.), and instead perhaps choose something like the Silver Popular, *Populus alba*.

This tree is medium sized and also quite colourful which would add a distinct charm to wherever it is placed. Although tall, the soft foliage is light and airy and doesn't enclose a space, nor particularly blocks a view of what is behind it. When added alone it can add scale and natural beauty to what would otherwise be a sterile view (Figure 58: Populus alba framing a house, via Altervista).



Figure 58: Populus alba framing a house, via Altervista

Interior Decoration

Although perhaps unorthodox and not particularly common in comparison to simple plants, trees can also serve to improve the interior environment of a house or building. I'm particularly thinking of *bonsai* – carefully crafted miniature trees. Using these, trees can serve to not only expand on the natural beauty of the exterior world, but also bring a sense of belonging and calm to the interior environment.

So, what traits and characteristics are typically needed in a bonsai tree? Well, one obviously has to choose a species that is both hardy and one that will tolerate the environment that it is to be placed within – i.e. indoors a shade resistant tree would be useful since it shan't be getting full sunlight. One then must choose what style to attempt to recreate, whether the colour or size of the foliage is important, how many branches are formed, whether one wishes for it to be multi-stemmed, and so on.

Given the list I have been given I would perhaps choose *Cotoneaster horizontalis* (Figure 59: A beautiful Cotoneaster horizontalis bonsai). This is a naturally short tree which ensures that it is easy to train. It produces relatively colorful, small leaves and berries, as not to look preposterous on a dwarf tree. It also has dense branching with considerable girth which provides a distinctly ancient and empowering look.

From a maintenance and health perspective they are easy to manage. They are adaptable to many types of soil, are fairly hardy, and are drought and shade resistant[84] – all of which make caring for the species indoors easy from a bonsai perspective.



Figure 59: A beautiful Cotoneaster horizontalis bonsai

[84] "How to Grow and Care for Cotoneasters", The Garden Helper, http://www.thegardenhelper.com/cotoneaster.html

Conservation

Finally, another use for trees in the surrounding environment is for conservation. This is particularly prevalent in reforestation and ancient woodlands. Unlike the previously mention aspects, trees for conservation uses are rarely chosen for their aesthetics. Instead they are chosen for their natural right or place within the ecosystem, their contribution to the local flora and fauna (such as nesting birds) and lastly for their traditional place in this country.

For example, you are unlikely to see the Norway Spruce used for conservation in this country, but you might see such broadleaf's as Oak. For ancient woodlands, one such "indicator species"[85] is *Corylus avellane* – also known as Hazel – which appears alongside various other species in ancient woodlands (Figure 60: Hazel Woodland). From a conservation perspective hazel serves to help maintain ancient woodlands, as well as providing food and sustenance to many protected species of caterpillars – as well as also mammals such as squirrels.



Figure 60: Hazel Woodland

[85] "Ancient woodland species", Woodland Trust, http://www.backonthemap.org.uk/theproject/analysis/species

§3.2 – Plant Handling Processes

§3.21 – Storage after Lifting – Containerization

In a commercial setting, there are many various means by which woody plants can be stored whilst awaiting a sale. For online or distance sales, cold stores may be used to enhance the time one is able to store the stock, as welln as being able to minimize labour costs, whereas in a live setting – where customers may wish to observe and examine the stock – containerized, root-balled or bare-root plants may be preferred.

Containerized woody plants (Figure 61: Exterior Containerized Stock in a Local Garden Centre) are perhaps the most familiar and prevalent in a retail setting, although it is not used exclusively therein. One of the benefits of such stock is the ease of movement – since they do not require "lifting" from the earth in the traditional sense. This benefits retail companies for several reasons. The first is that stock can be moved in to replace sold plants as soon as is feasible, rather than having to wait for favourable environmental conditions to lift. Plants can be maintained and kept alive for long periods of time. Furthermore, there is little risk of the root-ball, or bare-roots, drying out if there is some degree of irrigation – indeed, even that is minimized if the stock is kept outdoors as in the below photograph.

Lastly, one of the most obvious reasons is the ease of selling. The difficultly for a customer to purchase and keep woody stock alive until transplanting is minimal for containerized stock. They can be moved easily from the shop to the final location, and require few precautions when it comes to handling, relatively speaking. That being said, from a health perspective containerized stock tends to have a lower survival rate then root-balled or bare-root trees, but for many this is offset by the ease and practicality that containerized stock provides.



Figure 61: Exterior Containerized Stock in a Local Garden Centre

§3.22 – Labelling of Woody Plant Stock

Once again from a retail perspective all that the customer may expect from labelling is the taxon and some basic information concerning the species and care. Some plants require "plant passports" and these will be labelled appropriately, as will be discussed. Basic methods of labelling are shown below:

- *Basic information for non-scheduled stock*. This category is typical of containerized stock, and can be broadly broken down into two further categories: collars and soil inserts (Figure 62: Bonsai LabelThis is typically seen on novelty trees, such as bonsai or small hybrids, as well as bushes, such as *Rosa spp.*. They are typically generic and not-too-enlightening, and may at worst contain only the taxon and common name, and at best a brief description of the species with some care considerations (Figure 62: Bonsai Label).

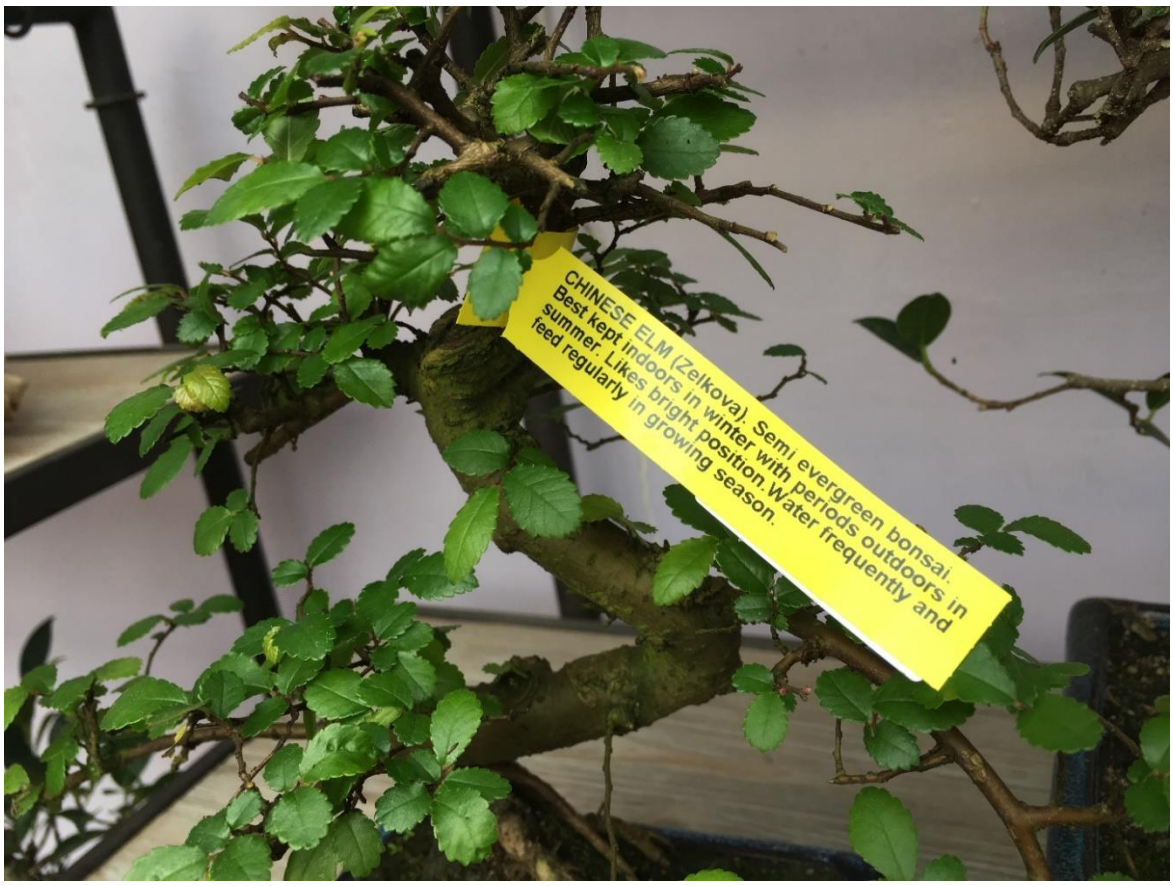


Figure 62: Bonsai Label

- *Full information for scheduled plants*. These are "proper" labels found on plants that are subject to the Plant Health Order 1993. For the most part it comes in the form of a Plant Passport, a document and label that accompanies the woody plant on its travels, and which hold important information regarding the woody plant itself.

  For example, let's take a look at Figure 63: Plant Passport Label. This label contains all the basic information that one might expect, plus some extra. First of all, we have the taxon and size of the stock. In this case it has a girth of 12-14cm making it a standard. Some labels have some variation on the later word included. i.e. "Std", "S" and so on. The size of the pot is also included along with the nursery's name and order number for traceability.

We then come to the plant passport itself. With the tree that we are currently examining the passport states "*EC Plant Passport UK/EW 20090*". "*EC Plant Passport*" simply states that the label should be taken as the sole part, or one part of many, of the whole plant's plant passport. "*UK*" states that the plant's origin is the UK, and this may differ depending on the country of origin. "*EW 20090*" is the stocks APHA – Animal and Plant Health Agency – registration number which aids traceability in the event of a disease outbreak, or such other similar incidents. Other information that may be included on a label is whether the plant is zone protected – *"ZP"* – whether it is a replacement passport – "*RP*" – and other assorted tractability information such as batch number, quantity and so on.



Figure 63: Plant Passport Label

§3.23 – Bundling Stock

Bundling is the preferred method of transporting bare-root stock, but *not* containerized or root-balled stock. It simply described the method by which woody plant stock are "bundled", or bagged, en masse for transport. Although I was unable to find an obvious example on bundling at my local garden centre, I did manage to find an example where a good number of bare-root plants were collected together ready for selling (Figure 64: bare-root plant stock).

When it comes to bundling, it should only be performed with groups of the same species. If there is more than one bundle, then they should ideally each contain the same number of stock – up to 100 for seedlings, down to a mere two for trees with a girth of 10-12cm. The roots should always be on the same side, and the stems secured together with some form of tie. The roots should in theory be protected by some means in order to not damage them – one good way of doing this is by enclosing the roots, or

indeed the whole plant, in polythene bags with the darker side faced inwards. Any shoots growing from the main stem may need to be tied to prevent them becoming damaged or broken during transport.



Figure 64: bare-root plant stock

§3.24 – Packing for Transportation

As with many things to do with woody plants, there are a number of different ways by which woody plants may be packaged ready for transportation. One is, as previously discussed, containers. These are fairly simple to manage and move (Figure 61: Exterior Containerized Stock in a Local Garden Centre) and should, clearly, not be stacked.

Larger stock, especially that which is root-balled, does well to be packaged in securely tied plastic sacking that covers the entire root zone. It is preferred if the interior is black, to help retain moisture and heat, whilst the exterior is white, to reflect excess heat (Figure 65: Root-Balled Tree ready for Transport). These, too, should not be stacked.

Smaller, lighter root balled stock can simply have their root-ball enclosed in netting. This, does, however require some maintenance when it comes to irrigation, and they shouldn't be left in this state for an excessive length of time (Figure 66: Smaller Root-Balled Stock).

Bare root plants can be stored in black polythene, or can have their roots temporarily stores in a light mixture of peat or other similar porous substances.

In terms of transportation itself, many trees in a retail setting are moved by their lonesome in cars or vans, but in a larger commercial setting lorries, and indeed pallets therein, are often used due to the

considerable bulk and weight of larger stock. All stock, in whatever setting, should not be crushed or broken, and should be protected from the outside elements, as well as drying of the root zone.



Figure 65: Root-Balled Tree ready for Transport



Figure 66: Smaller Root-Balled Stock

§3.25 – Transport Methods

I struggled to find anyone particularly knowledgeable at my local garden centre whom I could interview about the company's approach to transportation, so I elected to email a local nursery to get their views on the subject. Below is a witness statement with a transcript of what was said.

Learner Name	Marley Sexton
Qualification Title	ABC Level 2 Certificate in Arboriculture
QAN	
Location of Task	Perrie Hale Nursery
Date	1 Feb, 2017
Witness Name	Faye Davey (BSc, PhD)
Relationship to Learner	None/Business Owner
Contact Detail	01404 43344, faye@perriehale.co.uk

Unit(s) / LO(s) / AC(s)	Description of activity undertaken
Unit 3, LO 3, AC 5	Emailed tree nursery owner concerning the methods of transport that they use for their woody plant stock.

Witness Statement
"*Hello Marley,* *Most of our plants are transported bare root as they are easier and lighter to transport without the soil and they are also easier to plant the other end. We only transport trees bare-rooted in the winter when the trees are dormant. The root systems are surprisingly tough with the species that we sell bare root, to transport them they are placed in co-extruded bags that are a tough plastic bag - white on the outside and black inside these are purposely used as they keep the plants moist and also protect them from cold. Plants with more delicate root systems would be sold in pots.* *Using bare-rooted also encourages the plants to put on root growth when they are planted as they are 'stressed' into surviving, sometimes root balled plants just 'sit' in the soil they arrive in and use up the nutrients in the soil they arrive in and don't like to put out roots to the new soil – it takes them longer to get established.* *We do not sell bare-rooted for the health benefits, however it is possible that there is less risk of transporting insects that could cause damage or spread disease, though our nursery is regularly inspected so this should not occur anyway*"

We confirm that the above is an accurate record of the activity.

Learner Signature	*Marley Sexton*	Date	01/01/2017
Witness Signature	*Faye Davey (BSc, PhD)* via Email	Date	01/01/2017

I confirm / do not confirm (Delete as appropriate) achievement of the assessment activity

Action Required			
Assessor Signature		Date	
Internal Moderator/Quality Assurer signature (if sampled)		Date	

§3.26 – Root Protection Pre-Planting

The protection required for the root zone pre-planting depends highly upon which transport method one has chosen. For example, containerized plants need little protection comparatively – they need only to be kept moist right up unto the moment of planting when they are removed from the pots and placed into the ground.

Root-balled plants need too to be kept moist and this can be slightly more challenging then with containerized plants, but only slightly so. For the most part correct irrigation alongside the aforementioned transport methods – such as sacking or polythene bags – will surface.

Bare-root plants are perhaps the trickiest. The roots of tree stock will rapidly dry and disintegrate in the open air, and on top of this they are difficult to irrigate and keep moist. For this reason, a commonly used technique for maintaining the root zone at the site of planting, and preventing damage, is to bury the roots ever so slightly in a mixture of light moist soil, such as peat or sand. i.e. one can, upon receipt of the given stock, lay them on the ground and cover the roots gently with soil, without firming, so that they can be easily removed when the site is ready. One can further cover the soil mound with sacking should they require to be kept overnight.

§3.3 – Methods of Planting Woody Plants

§3.31 – Semi Mature and Standards

When it comes to selling, or purchasing trees it is obvious that the size of the target species is relevant to the decision at hand. However, without clear standardized guidance what might be considered a "standard" tree by one seller, might be called a "semi-mature" by another. This discrepancy is especially damaging when it comes to online sales since the buyer can obviously not see the tree and judge its size for themselves.

Thankfully over the years many guidelines and standards have been put in place to provide uniformity throughout the industry. These slot all trees into neat "size categories" which can then be referred to by any buyer or seller to provide guidance. In this country one set of guidelines is the British Standard BS 3936. The size categories this outlines are shown in the table below.

	Size	*Girth ABH*[86]
Standard	Light Standard (LS)	6-8cm
	Standard (S)	8-10cm
	Select Standard (SS)	10-12cm
	Heavy Standard (HS)	12-14cm
	Extra Heavy Standard (EHS)	14-16cm
	Advanced Heavy Standard (AHS)	16-18cm
	Semi-Mature	18-20cm +[87]

This standard only applies to "stereotypical" trees with branched crowns. Feathered and multi-stemmed trees, as well as whips, are sold per their height. On top of this the BSI uses girth as an indicator of size primarily because the height of a tree can vary per numerous factors, whereas the girth of a tree grows steadily and is thus a better indicator of age and maturity.

Two major groupings of tree sizes can be seen from the above table: standard and semi-mature. Standard is often broken down into further categories, but broadly a standard tree is any tree with a girth of between 6 and 18cm, and a semi mature is any tree above this size. Not included in the above table are related sizes such as half-standards (around 4-6cm girth).

As we can see from the below photograph (Figure 67: Standard (Left) and Semi-Mature (Right) Trees, (c) Deepdale Trees), showing a standard and semi-mature tree, there is a significant difference in the overall height, the breadth of the crown and, of course, the size of the trunk. Furthermore, as to be

[86] *At Breast Height*

[87] In practice, only trees with a girth of above 20cm are considered semi-mature, whereas 14-20cm is "extra heavy standard"

expected, there is a notable difference in the size of the root zone, which is to be expected as it spreads out as the tree ages.



Figure 67: Standard (Left) and Semi-Mature (Right) Trees, (c) Deepdale Trees

§3.32 – Planting Different Types of Trees

Depending upon the types of tree employed for a given job the method of planting such is varied. For example, the technique required to plant a extra heavy standard tree is obviously different from the means by which a small bare-root whip will be placed into the ground. I shall briefly describe each method within the paragraphs below.

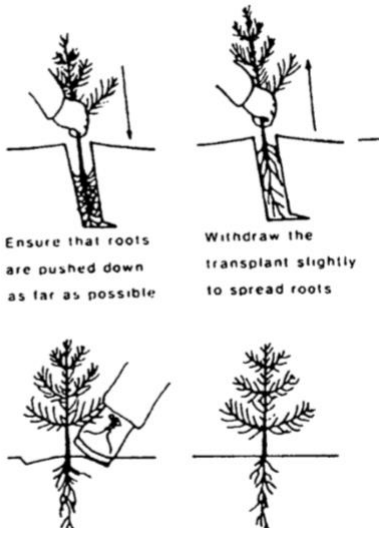


Figure 68: Notch Planting, via The Forestry Commission

One of the first considerations that must be made for all types of nursery stock is choosing a species that is suitable for the ground that it is to be planted within. For example, it is no good planting a tree which enjoys well-drained sandy soils in a heavy clay soil – it would simply not survive!

The next consideration is the time of planting. Full hardy deciduous trees should be planted during dormancy from November to March, although ideally before January so that they have time to establish new roots in advance of the growing season. Half-hardy plants should only be planted in spring. Evergreen trees should be planted either side of dormancy – in October or March – when the soil is not frozen or overly cold.

Lastly it is always worth taking note of the soil and the surrounding environment and looking for evidence of any

unfavourable conditions or pathogenic or parasitic organisms. If there is any doubt in the suitability of the site it is often worth investigating further or holding off on planting in order to avoid a costly death in the future.

Once happy with the site and conditions we can quickly proceed onto planting after receiving the plant stock from a nursery. For cell grown or bare-rooted whips, below 1-1.5m, notch planting is preferred (Figure 68: Notch Planting, via The Forestry CommissionFigure 68: Notch Planting, via The Forestr). To perform this one first screefs a small circle of turf before making a slit in the ground with a spade, to a depth of ⅔-1ft deep, and pulling it back to expose a small gap in the soil. The tree stock is then placed within the opening, pulled up slightly to prevent the root being compacted and crushed, and then the ground surrounding the opening is firmed with the heel to fill in any gaps and push out air pockets. The base of the tree should be level with the lay of the earth. Should the tree need to be planted above ground level a mound or ridge is first produced before creating the slit.

For container grown trees which are not root bound the best method is to dig a pit as deep as the root mass and place it therein. Following on from this one can then backfill the hole and firm the soil around it[88].

For standards pit planting is the preferred method. This technique is simple in theory, but slightly more complicated and time consuming in practice. It merely involved digging a pit of depth and width 20cm greater than the extent of the root system, forking the base and sides of the pit to improve aeration, and then lowering the root mass into the hole. The roots should not be so deep as to lay across the base or side, but rather should "hover" over the surrounding soil. This is so that when the pit is backfilled, with a topsoil/fertilizer/compost mixture, the roots are spread out and neither crushed nor compacted. This ultimately gives the tree the maximum possible chance at survival, since the roots will be able to spread out efficiently and quickly, as opposed to staying confined to the walls of the pit. After backfilling the soil is firmed and any aftercare requirements are undertaken when needed.

[88] "How to Plant Containerized Trees", ArborDay, https://www.arborday.org/trees/planting/containerized.cfm

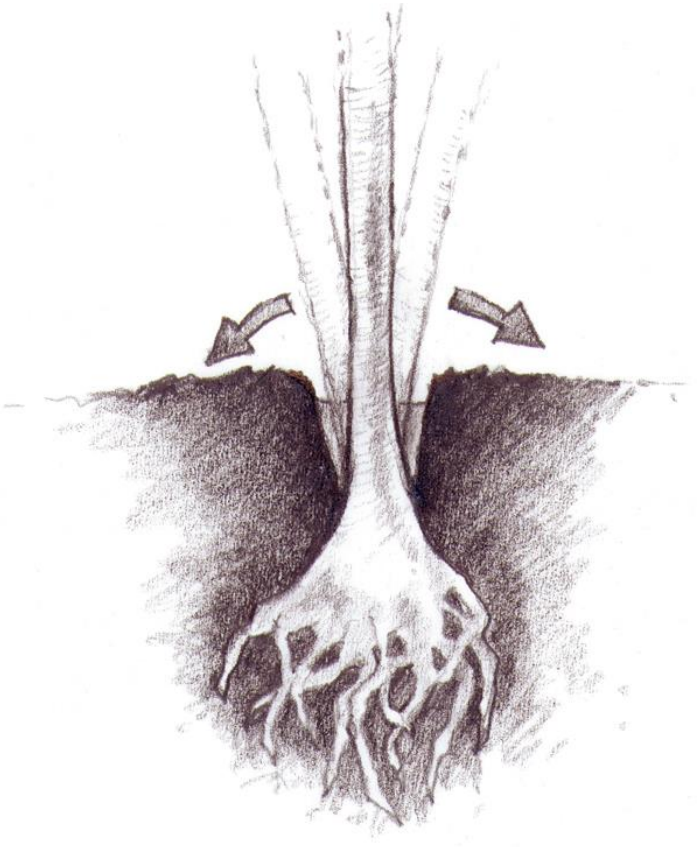


Figure 69: Crowbar Hole, via Fine Gardening

The goal of staking is to provide additional support for a tree that may be unable to support itself. Possible reasons for this include the root system being too compact or small compared to the crown, so that in wind the tree has poor anchorage and may become windblown. Another possible reason for staking is to support trees that may have weak stems that are prone to snapping. Lastly excessive swaying in the wind can form a "crowbar hole" (Figure 69: Crowbar Hole, via Fine Gardening) in the ground which may encourage rot to develop[89].

Despite all this, there are disadvantages however – especially in the long term - so it should only be considered if absolutely necessary.

All stakes must conform to BS 5236 and BS 1282 – and thus should be made of pressure impregnated softwood timber, such as larch or chestnut, and should be appropriately long for the task at hand.

Low staking is preferred so that the trunk may sway in the wind which encourages stem thickening (i.e. compression or tension wood), although high staking is appropriate if the crown is especially heavy or dense.

Stakes should be driven at least 60cm into the ground leaving between 2.5-3cm between the stake and the tree's trunk[90]. Tree's should then be tied to the stake in order to restrict the movement of the stem. To tie a tree to a stake one particularly useful method is to use a belt of some description, and some padding. Place the padding around the tree to ensure that little damage will be caused by the tie, then wrap a belt around both the stake and tree and adjust so that there is some, but not a lot, of movement in every direction. Alternately a band of some sort can be wrapped around in a figure of eight and tied between the stake and tree.



Figure 70: Single Staked Tree, via Jacksons Fencing

For standard trees, single staking is often adequate at providing support. In this scenario, a single stake is used and tied to the

[89] "To Stake or Not to Stake", Fine gardening, http://www.finegardening.com/stake-or-not-stake

[90] "Trees: Staking", RHS.org, https://www.rhs.org.uk/advice/profile?PID=208

stem using tree pads, spacers and/or belts – or really any other adjustable means to tie the tree to the stake that does not cause rubbing or girdling (Figure 70: Single Staked Tree, via Jacksons Fencing).

For an extra-heavy standard, a more robust system of staking should be employed. The reason for this is that the considerable extra bulk and weight of an extra-standard can easily pull over or buckle a single stake. In heavy, gale force winds the tree may still fall – the stake simply being ripped out of the ground. One technique of preventing this is to use two or more stakes to support the tree from multiple angles. If positioned correctly a tri-stake method can add extra layers of support for an otherwise heavy tree – a storm that may be able to rip one stake out, may struggle with two, and even more so if it also requires pushing down on a third. Another method is by using wire with padding to pull, or "guyed", the tree in three directions – thus providing outward tension pressure to combat any swaying or movement (Figure 71: Tree Staking methods, via ShadeTrees.com). Regardless of the method chosen, all stakes, wires and so on should be removed within 2-3 years – after the tree is established – and regularly adjusted to prevent damage to the stem, for example by the ties cutting into the bark as the tree's girth expands.

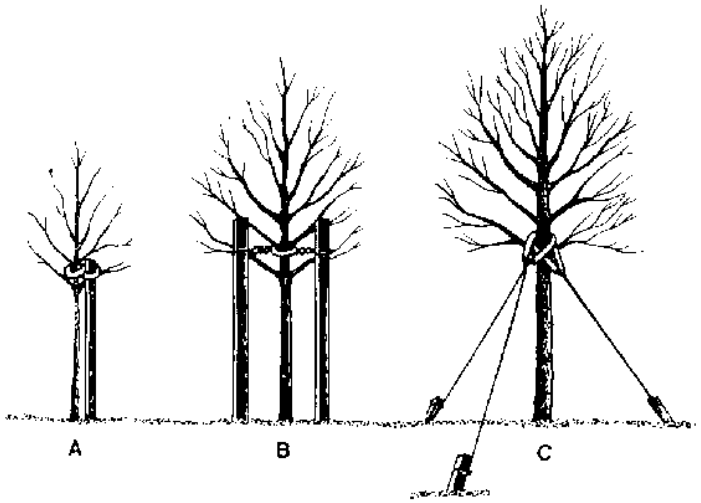


Figure 71: Tree Staking methods, via ShadeTrees.com

§3.34 – Backfilling and Mulching

When backfilling a slit or planting pit care must be taken to ensure that the depth and width of the given hole is *larger* than the apparent size of the given stock's root system. This is so that roots are not twisted, crushed, compacted, or otherwise laid against the walls of the planting hole. Any damaged roots themselves should be trimmed, and furthermore they should always be kept moist, else severe and potentially irreparable damage may occur.

Once a tree has been carefully lowered vertically into the pit, or otherwise, and the roots hang freely, a soil and compost or fertilizer mixture (but not fresh manure!) should be slowly backfilled into the pit so that it falls gently around the roots. The woody plant should be slightly moved up and down to ensure that the soil falls between the roots, and so that they are spaced out and not twisted.

Every 15cm or so the soil should be firmed – with sandy soils being firmed harder than clay soils, particularly in wet conditions – up unto the point where the soil meets the root collar of the tree. At which point any depressions in the earths should be filled in. All that is left is to re-firm as necessary.

Following on from planting, or at any time during the tree's lifespan, it may be necessary to mulch the surrounding soil. This is, put simply, where a layer of material is placed on top of the soil with the express goal of protecting the root zone, trapping moisture and heat within the soil, reducing the proliferation of weeds and other pests, reducing wind or rain derived erosion, inhibiting soil compaction and, finally, potentially increasing the fertility of the soil if a biodegradable material is chosen.

To mulch a newly planted tree it is worth first removing any weeds or undesirable creatures. For the former, this is best performed by hand or hoe, although weed killers can be used if care is taken not to damage the tree itself. Then it is simply a case of spreading a mulch over the desired area, to a depth of 15cm. For inorganic mulches a cut where the tree can sit within should be made in the fabric before laying it down.

There are numerous different types of mulches one may use to do the job. In a broad sense, anything which may degrade into toxins – such as spruce chippings - or which rapidly decays and feeds nitrogen hogging microorganisms - such as saw dust - should be avoided. A list of some organic and inorganic mulches is listed in the table below.

Organic Mulches[91]	Inorganic Mulches[92]
Compost or Peat	Stones, Rock and Gravel
Cocoa Bean or Shell	Black Plastic
Grass Clippings	Geotextile Membranes
Wood chippings	White Plastic
Paper or Cardboard	Red Plastic
Shredded Bark	
Leaves	
Well-rotted manure	

One particular mulch I have come to know quite well is shredded bark (Figure 72: Shredded Bark Mulch) which causes endless problems where I work. It is worth noting that in this case the bark sits upon a geotextile membrane.

[91] "Types of Mulch", Grow Anything, http://www.growinganything.com/types-of-mulch.html

[92] "Synthetic and Inorganic Mulches", About Gardening, http://gardening.about.com/od/gardenmaintenance/a/Mulch_2.htm



Figure 72: Shredded Bark Mulch

Ultimately, however, it is a decent mulch. With a membrane underneath the mulch only needs to be to depth of 50mm, whereas upon raw soil a depth of 100mm should be maintained. It had little to no effect on the volume of nitrogen within the soil, and it slowly biodegrades providing limited nutritional benefits to the trees. From experience, I have noted that it retains moisture and heat particularly well – even in freezing conditions where the top centimetre or two has frozen solid. It also suppresses weeds marvellously, although I have observed mushrooms breaking through in areas without a membrane layer.

As for the negatives, however – one that is particularly bothersome in that it can lead to "over mulching". My employer decided the best time to mulch was in later summer. After leaf drop began, and due to the location being enclosed from the wind, a thick layer of leaves built up upon the shredded bark. This would naturally come hand in hand with its own problems – such as reduced water and oxygen penetration, and the formation of a new humidified layer within which weeds and fungi can take hold. It is also difficult to remove without also removing a large proportion of the desired mulch. For this reason, I would argue that shredded bark is best suited for areas with only a few trees, as opposed to a wooded area which essentially mulches itself come autumn.

§3.35 – Unfavourable Conditions and How They Can be Managed

There are limitless ways, some obvious and some not so, that trees can be damaged by unfavourable circumstances – especially in an urban environment. Some of these are discussed below.

One of the most obvious and avoidable means by which a tree may be killed is by improper handling and planting. This is best managed through good planting practices as described previously. If trees are planted too deep they may starve of water and oxygen, while if planted to shallow they may dry out or be damaged mechanically, or else crushed. Plantings that leave a depression around the trunk may encourage bacterial and fungal growth if a shallow film or "pool" of water develops.

Another easily managed condition is poor soil fertility (or over-fertility) – this typically manifests as obvious physical and visual symptoms, such as chlorosis, and can be carefully managed through the addition of fertilizers or chemicals. Combined with the aforementioned good planting practices tree can be easily established and growth could be rapid.

Other unfavourable site conditions include:

- Pedestrian or vehicular traffic. This is best managed by creating a barrier of some description around the base of the tree (Figure 73: Raised Tree Bed to Discourage Pedestrian Traffic), potentially up unto the drip-line, to prevent traffic causing soil compaction. Planting in low-traffic areas can optimize tree establishment.
- Toxic runoff. This may include industrial waste, grit, salt, and so on. Best managed through low-barriers or simply using resistant species.
- Air pollution. Mostly unavoidable in urban areas. Best managed through the use of resistant species. Non-resistance species may be prone to failure, so to optimize tree establishment in urban areas care needs to be taken to use the correct type of trees.
- Flooding. Also, mostly unavoidable in many areas (such as flood plains) – best managed by planting resistant species, or by only planting in well-draining, sandy or silty soils. There is a possibility to introduce and create a new soil zones in unfavourable sites – at some cost – but care must be taken not to introduce severe grade changes.



Figure 73: Raised Tree Bed to Discourage Pedestrian Traffic

§3.4 – Protection and Support Systems for Woody Plants

§3.41 – Newly Planted Tree Support Systems

Newly planted trees are particularly vulnerable during their early life, especially is they have come from stock where roots are restricted in comparison to their crown – i.e. container grown trees. There are thus many reasons why newly planted trees require support, many of which have been discussed in §3.3x, but two reasons are:

1. *To prevent the trees becoming windblown*. In a natural environment trees root systems are often just as expansive as the crown. This serves to anchor trees in place and prevent them being blown over by strong winds. In newly planted stock the root system is immature and often constricted at first, thus a support system, such as a stake, can serve to provide extra accourage while the tree's root become established in their new home.
2. *To help strengthen the stem.* In immature trees the stems can oftentimes be unable, on their own, to withstand what nature throws at them. By providing additional support, perhaps in the form of a stake once more, a tree can be gently acclimated to the surrounding environment – which may be different from where it was raised. For example, a tree that was nursed in a protected cove may struggle initially when placed on a windy coast. Thus, support can give time for the trunk to increase in girth, and strengthen, without placing undue stress upon the woody plant.

There are many suitable tree support systems available to the arborist, and I have extensively covered staking in a previous section. Therefore, it is worth now discussing an alternate method: sheltering (Figure 74: Tree Shelter with Mulched Soil). Best used for very young stock, they provide a tree with a highly favourable growing environment with extensive protection from damage – especially from the wind. It thus provides a cheap and cheerful means of supporting the crown of young stock whilst they become accustomed to the surrounding environment.



Figure 74: Tree Shelter with Mulched Soil

§3.42 – Damage by Rabbits and Deer

Besides the chemical, mechanical and man-made means of damage described in section §3.3x, there is – especially in rural settings – also the threat posed by wildlife. Two particularly damaging pests are rabbits and deer which can damage trees in the following ways:

1. Rabbits and deer can unfortunately ring-bark trees when feeding (Figure 75: Tree Ring-Barked by a Rabbit)[93], or can simply consume young seedlings or buds.
2. Deer can reach above many types of support and protection and eat the leaves, branches and buds of a young plant, causing extensive damage to the crown. Cattle and other large herbivores can also cause such damage.
3. Male deer can also fray trees[94]. This is where they rut their antlers up against the bark and branches to remove the velvet found thereon. This ultimately leads to circumstances where there are broken branches, torn foliage, stripped bark and even the tree being pushed over at an angle. This naturally occurs on younger trees where the crown is at the same height as the deer, and is not typically found on mature trees.

[93] "Rabbit Damage to Trees and Shrubs", Iowa State University, http://www.ipm.iastate.edu/ipm/hortnews/2010/3-17/rabbitrepair.html

[94] "Tree Damage by Deer", SACS.org, http://www.sacs.org.uk/folder-114-tree-damage-by-deer



Figure 75: Tree Ring-Barked by a Rabbit

Despite the risks there are multiple means in which newly planted trees and shrubs can be defended against rabbit or deer damage. One of the most obvious is to build a fence, or something similar such as a wire mesh (Figure 76: Wire Mesh Guard), around the given tree to prevent rabbits or deer getting close enough to cause damage. It is worth noting that since rabbits are proficient burrowers any fencing or netting should be buried up to half a foot deep to prevent them simply going under the barrier.

To protect a large number of trees, where it would be uneconomical to protect each individually, a large fence around the perimeter of the site is often sufficient to prevent deer from entering. Barbed wire is often also employed to deter any invasive behaviour.

Lastly trees can be protected from being girdled through the use of spiral tree guards (Figure 77: Spiral Tree Guard) which act as a sort of second, impenetrable, skin to a tree and inhibits the ability for rabbits and other such creatures to chew away at the bark at the base of the woody plant.



Figure 77: Spiral Tree Guard



Figure 76: Wire Mesh Guard

§3.43 – Damage by Grass Maintenance Equipment

Damage by grass maintenance equipment can often happen suddenly when due care is not taken to prevent it. There are two primary means by which damage can be caused, and they largely depend on the exact type of equipment used;

1. Pure mechanical damage. This is as simple as it sounds, and can often occur with small hand held strimmers or lawnmowers. It is merely a case of the blade encountering a part of a young tree or shrub, typically the stem, and it then causing mechanical, cutting or slicing damage at best, and a complete severing of the young, small trunk at worst. In the former case the wound can be an entry site for pathogenic infection or pest infestation, and beside this it causes extreme stress to the young tree as it must consequently compartmentalize the damage.
2. Soil compaction. For extensive patches of grass, a heavier, ride on lawn mower or similar device may be employed to maintain the turf. If this is the case then besides the risk of mechanical damage, there is also the possibility of soil compaction from the weight of the device – which can cause harm to the roots and suffocation in the long-term.

For both potential harms, there are simple, easy solutions to prevent them. These are:

1. Avoiding the base of the tree. To avoid mechanical damage, it is merely a case of avoiding any situation where a blade, or other such device, can come into contact with the tree – on accident or otherwise. Thus, by leaving a small patch of grass around the base of the young tree the risk is minimized. This can be achieved through either carefully manoeuvring around the base, or by installing tree guards or fencing to completely reduce the possibility., Although allowing the grass to grow is unlikely to have any particular downsides, if it is required to be cut it is often safest to do it by hand.
2. To prevent soil compaction, the area around a tree where large mechanical devices should not enter is larger than the above – often up unto the dripline. This reduces the possibility of compaction within the rootzone. If grass is required to be cut within this area, lighter handheld devices or strimmers would be preferable, but taking note of the aforementioned risk of mechanical damage.

§3.5 – The Aftercare of Woody Plants

§3.51 – The Importance of Aftercare

Trees, from an economical perspective, are an expensive investment. Not only does one have the initial cost of purchase, but also the associated costs such as planting, pruning, support, and so on. To not place any importance on aftercare would be the same as buying a new car and never putting it in for servicing! – the result would be the same for both: damage, reduced value and potential failure.

Indeed, this is one of the most important reasons for performing aftercare on newly sown woody plants. Without basic precautions and care a tree has a high probability of failure – indeed, half of all trees die within ten years of planting due to neglect. If the tree in this situation does not fail, then there may be a significant reduction in vigour, growth or resistance to disease and pests which will lead to an increased risk of death the longer the lack of care is continued. From an economic standpoint neglect reduces the value of the tree alongside the costs of bringing it back to normality increasing year on year. On top of this physical aftercare is important from a short-term perspective, after all it is not ideal for a newly planted tree to become windblown because one neglected to stake it.

A second reason for performing physical aftercare is safety. A tree where rot has been allowed to take hold due to insufficient pruning, for example, or one that has been allowed to grow unchecked – perhaps now overstretching roads, railways, powerline, or so on – presents a severe risk to the safety of those around it. All it may take is a storm to dislodge deadwood or a particularly strong gust of wind to bend it into powerlines, and there suddenly appears a risk to life and limb. After all, for instance, many branches, even rotten ones, weigh more than the average human and can cause severe injury when falling from height. From a more selfish perspective, if one owns a tree which has been poorly care for, and then from which a branch falls onto a car, house or – at worst – a person then it opens the individual up to legal action. In the former cases, it may simply be a civil suit, whereby one is sued for damaged, but in the later it could be a criminal case resulting in imprisonment.

§3.52 – Three Year Aftercare Outline

After planting a newly purchased tree in sterile ground there are a few general tasks that must be taken care of in the first three years. These I have outline below.

Year 1	[1] Staking [2] Irrigation [3] Fencing or Shelters, if Necessary [4] Mulching, if Necessary [5] Pruning
Year 2	[6] Weeding [7] Fertilizing, if Necessary [5] Pruning
Year 3	[6] Weeding [7] Fertilizing if Necessary [1] Removing Stake [5] Pruning

1. Staking is best performed early on after planting – as previously discussed. This ensure stability and straight growth and prevents the wind, amongst other such things, placing undue stress on the young tree. Ideally stakes are kept low and are used for the shortest time possible, but in reality, they tend to kept on for between 18 and 24 months. Thus, at the beginning of year three stakes should be examined and removed if no longer necessary. Stakes should also be checked continually throughout the years to ensure that no damage is being caused to the trunk of the given tree.
2. If the tree is planted in overly well-draining soil, irrigation may be required to ensure that the root zone stays moist during dry periods, especially during spring. This may be performed by basin watering, with furrows, or with sprinkler, soaker or drip systems. For whatever method is chosen care should be taken to ensure that no water sits around the base of the trunk, which can encourage bacterial and fungal growth. In poorly draining, clayey soils, a method of directing water away from the root zone may need to be installed, at perhaps some great cost. Irrigation should be performed during any dry period, by especially within the first year when the tree is at its most vulnerable due to transplant stresses.
3. Another task that needs to be performed in the first year, preferably as soon as possible after planting, is the erection of fencing, stem guards or other methods of physical deterrent to damage – either from animals or people. Many of these techniques can be installed easily (but not necessarily cheaply) and can be left for some years with only minimal maintenance required.
4. Between mid-summer and mind-autumn in the first year, mulching may be required. This has been discussed extensively previously, but a long-lasting, durable mulch – such as shredded bark or synthetic membranes – is often a worthwhile investment and can be placed quickly and painlessly. For less resilient mulches, such as leaves or peat, yearly mulching may be necessary. The goal of mulching is to help the soil retain moisture and heat, as well as reducing the proliferation of weeds.
5. Pruning is a yearly task which is often performed in the dormant period. The first target for any pruning activity is dead, decaying or damaged branches or shoots. Basically, any tissue that is serving as a host for infections, or that could be an entryway for such, should be removed to help preserve the overall health of the organism. The next target should be any crossing branches, any overly long branches that extend way beyond the crown and any branches which affect the overall aesthetics one is intending to create – for example if one side of the tree has twice the branches then the other, then it may be a case of thinning that given side out to create a more balanced look. Any suckers or other such growths should also be cut back to the stem, or root.
6. Although trees should be planted in weed free ground, frequent weeding in nonetheless a necessity. This should be done on a yearly basis, at the very least, although I would argue that it should be performed on a seasonal basis – however, this may be neither economical nor feasible for more than just a couple of trees. There are many means by which weeding can be performed. I personally favour hand-weeding or hoeing as if performed correctly this reduces the risk of damage to the tree, although for many it makes more sense economically to use herbicides or other chemicals to destroy unwanted plants. For the latter, there is a choice between sprays or granular herbicides, with the former being slightly more targeted whilst the latter is more of a nuclear option.
7. Fertilizing can often do more harm than good, so care should be taken before deciding to add nutrition to the soil. It is often useful to do a "yearly review" and examine the tree for signs of nutrient deficiency, and if such is apparent *then* move forward with a fertilization program. It is unlikely that such will ever be required, except in the sandiest of soils, and applying fertilizer needlessly can not only damage the tree, but also encourage the growth of weeds. If performed with diligence, however, fertilization can greatly increase the vigour of woody plants.

§3.53 – Causes of Failure to Establish

There are many reasons why trees may fail to establish after being planted, some of which are obvious and some not so. Four reasons are described below.

1. *Improper choice of species*. One of the most common reasons for trees and shrubs failing to grow on successfully is the improper choice of species for the given environment that it is to be planted within. For example, planting a salt-intolerant species next to the sea would likely lead to a significant chance of failure. Likewise, tree's loving sandy soils would be unlikely to thrive in clayey soils, and vice versa. Ericaceous shrubs planted in limey soils would also be likely to fail to establish, and likewise for lime loving plants in acidic soils. There are also other factors besides soil conditions. For example, humidity, pollution, pathogenic tolerance (so no planting orchards in fire-blight risk zones), and so on. Proper selection of trees that can resist what the local environment will throw at them is perhaps the most important aspect concerning the long-term chances of survivability.
2. *Improper protection*. Another common reason for trees and shrubs failing to establish is a lack of forethought concerning the risks from predators, humans or pathogens. Although the latter is difficult to defend against, the former two can easily be prevented with the introduction of physical barriers, as previously discussed. In an urban setting vandalism is a common cause of reduced tree vigour and death (Figure 78: Damaged cause by an axe vandal, via the BBC), whilst in a more rural environment herbivorous predators such as deer, rabbit, cattle and horses can quickly decimate a woody plant if adequate protections are not installed. These I have described in previous sections.



Figure 78: Damaged cause by an axe vandal, via the BBC

3. *Neglect*. Perhaps one of the most obvious causes of trees failing to establish is simple neglect. Whether through improper aftercare or simple ignorance, neglect is one of the leading causes of tree death. A good maintenance routine, with careful pruning, irrigation, staking, mulching and so on – especially within the first year – is vital to ensure that woody plant stock establishes itself well and can survive on its own.
4. *Improper handling*. Another reason for trees failing to establish results from actions taken before the tree has even been planted. Poor handling techniques, such as dropping the given tree stock or allowing the roots to dry out, will naturally place severe stress upon the tree when

it is eventually planted. If a tree's root has been damaged, for example, then this causes the tree to have to work harder to get a foothold in new earth and inhibits the ability for the organism to absorb water and nutrients which places it at a significant disadvantage compared to well-handled stock. Another factor is the time of planting. For example, planting trees during the dormant period is preferred, and handling them and planting on during summer would also cause the tree a great deal of harm long term.

§ 4

The Principles of Tree Surgery Operations

§4.1 – Understanding the Principles of Tree Surgery Operations

§4.11 – Crown Lifting

The crown of a tree can be thought of as all the plant material between the lowest branch and the uppermost tip of the stem. Crown lifting, then, could be easily visualized as "lifting" this matter up so that it begins further of the ground then before. To do this it is clear that one must remove the lower branches in an upwards fashion until the desired crown height is achieved (Figure 79: Before and After Crown Lifting, via WildWoods Dorset).

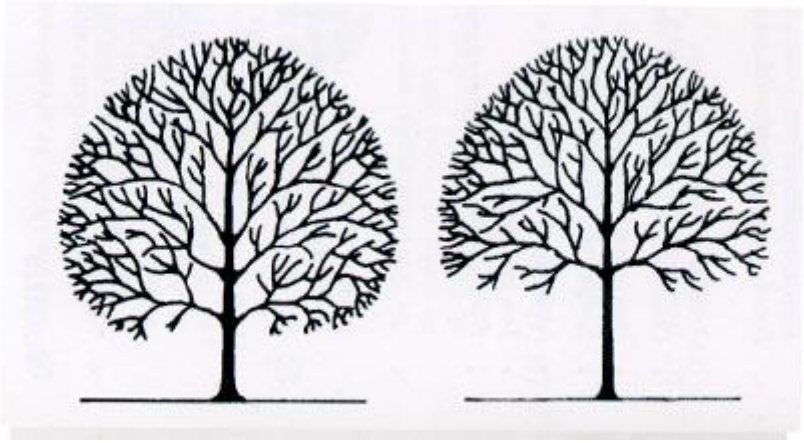


Figure 79: Before and After Crown Lifting, via WildWoods Dorset

The purpose of this is to ultimately create clearance under the tree. Obvious reasons include pedestrian and vehicle access – indeed, a clearance of 5.2m on a highway is required by law – but also such reasons as improved visibility, light penetration and safety.

Ideally crown lifting is not performed on conifers as they can often look odd without their bottom branches – for example *Cupressus* × *leylandii*, despite being able to grow to well above the 5.2m clearance guidelines, would look truly top heavy and bizarre with the crown lifted to such a height. Indeed, even with the 2/3 crown to 1/3 clear trunk ratio rule of thumb it would still be unappealing to the eye!

Such is not without its risks however. For large mature trees crown lifting can cause excessively large wounds when the oldest and largest branches are removed, and it is therefore not advised. Likewise, any pruning which may result in instability is also often not worth the risk[95].

§4.12 – Crown Thinning

Best performed in summer or autumn, "*Crown thinning is the removal of a portion of smaller/tertiary branches, usually at the outer crown, to produce a uniform density of foliage around an evenly spaced branch structure*."[96] (Figure 80: Before and After Crown Thinning) This is to say that the crown, in this scenario, is thinned by removing branches which are needless, but also which are neither part of the primary stem nor major secondary branches. Instead smaller branches which may lead to problems are

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[95] "A brief guide to tree work terminology and definitions", The Arboricultural Association, http://www.trees.org.uk/Help-Advice/Public/A-brief-guide-to-tree-work-terminology-and-definit

[96] *See* 95

to be removed. For example, small branches that cross major branches are removed, and dead, wounded, malformed or infected wood is often removed first, with subsequent branches removed according to structural soundness (angle of crotch), aesthetics (unbalanced crown) or practicality.

The numerous reasons for crown thinning include: Improving light penetration to the ground or buildings (Figure 81: Practical Example of Crown Thinning), improved shoot to root ratio, aesthetic improvements, decreased risk of deadwood falling in diseased trees, improved structural stability for weak species, reduced wind resistance to reduce the risk of branches snapping, reducing the stress on the plant in times of drought, and reducing the future risk of structural failure.

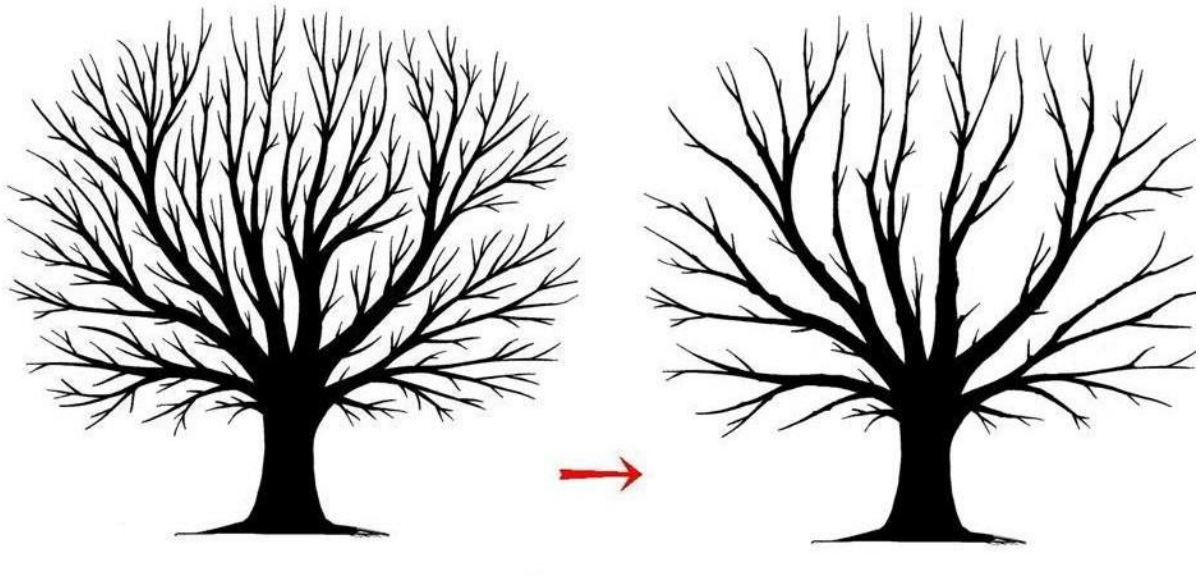


Figure 80: Before and After Crown Thinning via Arborcura



Figure 81: Practical Example of Crown Thinning, via PatreeCare

Crown thinning can be performed on a range of trees, although one that comes to my mind recently as being thinned is a local mature Willow – *Salix alba* – which sat outside a row of houses. Even in winter it was evident that it was blocking light entering the houses by its side, so I assume that they made the choice, while there was little foliage, to thin out the canopy ready for the summer. Indeed, any tree with fairly thick foliage would need to be semi-regularly thinned to ensure that the light to houses isn't blocked.

§4.13 – Crown Reduction

Standing in contrast to crown lifting, crown reduction entails lowering the height, or reducing the width, of the crown to a more acceptable level (Figure 82: Example of Crown Reduction). There are many reasons for performing this operation; for instance, if the branches overreach their designated area – perhaps over houses, in roads or into powerlines, or in cases where the main stem threatens the stability of the tree, then it is often useful to reduce the size of the crown. Other reasons include situations where the shoot to root ratio is unbalanced, or where disease has left the tree looking "stag headed", or where the weight of the limbs threatens their structural integrity.

Ultimately crown reductions, since it must be performed on the whole tree, lest an asymmetrical aesthetic should result, causes severe and widespread stress to the organism. With so many – and in fact perhaps all – branches experiencing shortening cuts there arises numerous possible entry wounds for decay to take hold. For this reason, it should be considered, in a way, as a last resort. It should also not be performed on trees that bleed heavily – indeed, crown reduction timing often follows the same rules as crown thinning and crown lifting.



Figure 82: Example of Crown Reduction

The preferred technique for crown reduction is as follows: "*The longest portion of the main branches will be cut back to an existing, smaller lateral branch that is large enough to assume the role of the branch. This is normally a third to half the diameter of the removed branch*"[97] (Figure 83: Crown Reduction Technique). All work should strive to achieve the stated goals, minimize total cuts and lend itself to a balanced and aesthetically pleasing appearance.

It must also be remembered that a tree will rapidly reassume its previous size, so crown reduction is an ongoing, maintenance heavy, operation that *will* need repeating.

Although like many of these techniques crown reduction is almost entirely performed on broadleaves, there are situations when it may need to be employed on conifers. For example, if there exists a Spruce – *Picea spp.* – forest through which power lines run then it may be the case that those trees under such may need to be semi-regularly reduced in height to prevent contact and to allow access when necessary.

[97] "Crown Reduction", Heritage Arboriculture, http://www.heritagearboriculture.co.uk/tree-pruning/crown-reduction/



Figure 83: Crown Reduction Technique

§4.14 – Crown Re-Shaping

Crown reshaping is just what it sounds like: reshaping of a trees crown to a more desirable aesthetic. This has been described as a "once only"[98] operation that brings a trees shape back in line with what is desired. Although crown thinning, lifting and reduction could all technically be called forms of crown reshaping, there is in reality a slight difference – in that crown reshaping can, and often does, leave the silhouette of a tree looking unbalanced. For example, this operation may take place if a tree overhangs a neighbour's garden (Figure 84: Reshaped Crown). In this situation, it would maybe be cut back to the fence on that side, leaving a rather lopsided appearance over the "correct" garden. Another example is if the tree hangs into a road, whereby the whole side of a tree may be reshaped.

[98] Crown Reshaping, Arbortec Tree Care, http://www.arbortectreecare.co.uk/tree-pruning-and-trimming



Figure 84: Reshaped Crown

An example of this that I have noted is with Oak – *Quercus robur* – alongside a road near to where I work. In this situation, the trees have *no* branches overhanging the road, even above a height of 5.2m. The reason for this, I assume, is that as it is quite a mature tree the branches would be heavy, and any interior deadwood or structural weakness' wouldn't be noticeable immediately. Given that they could be dislodged in a storm since they are quite exposed, they could have then fallen onto the local road below. These trees exist on a blind corner, in a national speed limit zone, so any debris of the road – even just secondary or tertiary branches, could lead to a major accident. Thus, for huge broadleaves - such as oaks - crown reshaping can be used to improve the safety of the local carriageways.

§4.15 – Formative Pruning

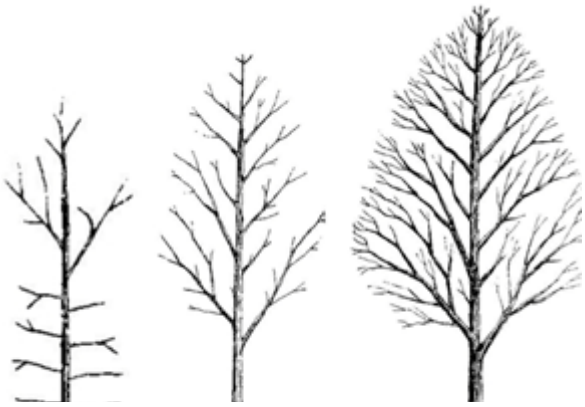


Figure 85: Formative Pruning

Formative pruning describes the methods involved in cutting back young tree stock with the desired goal of ensuring that the tree takes on a certain shape or form. In general, deciduous tree pruning is carried out in winter, whilst in evergreens it is performed in the summer[99] – although there are exceptions to these rules.

Techniques vary from species to species, but in general the goal is to, as the tree ages, ensure that there is a single primary dominant stem, that the trunk is clear up to a given height, that all trunk-branch unions are strong, and that the general

[99] "Trees: Formative Pruning", RHS, https://www.rhs.org.uk/Advice/profile?PID=385

structure of the crown is uncluttered with crossing branches and the like.

A species that this often should be performed on is the various varieties of apple – *Malus spp.* With this species there is often a tendency for the growth to become unwieldy, with branches crossing, and the like, which ultimately leads to unproductive and poorly trees. Robust pruning in the first few years, until the tree is semi-mature, often has huge advantages further down the line[100]. Typically targets are branches which compete with the stem for dominance, branches which have a weak union with the stem, as well as diseased or dying branches. They should all be cut back to just above an outward facing bud[101].

§4.16 – Pollarding

The technique of pollarding involved cutting back a tree to the same height every year. From the cut branches, many more branches typically arise. This is disfiguring and in many cases just plain ugly, so it is often only performed when absolutely necessary, or where aesthetics are irrelevant. Typical reasons for pollarding include reducing the height of trees to prevent contract with power lines, reducing shade or just general upkeep[102] – for example I have noted myself that many farmers will often pollard the bushes that surround their land semi-regularly, especially if they border a road.

A classical tree which was subject frequently to pollarding is the London Plane, *Platanus × acerifolia*. These were often planted without much consideration for their size. The result, given that they were often found in cramped urban environments, was that they needed yearly pollarding at some great expense – just to keep them in bounds. As council budgets, have evaporated these trees, alongside many others like them, have fallen into a state of little to no maintenance, leaving a blight on the local environment.

[100] "Apples and Pears: pruning new trees", RHS, https://www.rhs.org.uk/advice/profile?PID=164

[101] "Pruning apple trees", The Orchard Project, http://www.theorchardproject.org.uk/guides-and-advice/pruning-apple-trees

[102] "Pollarding", RHS, https://www.rhs.org.uk/advice/profile?pid=156



Figure 86: Aesthetically Unappealing Pollarding

§4.17 – BS 3998[103]

British Standard 3998 describes the best practice, timing and techniques for undertaking tree pruning operations. The goal would be to produce healthy, safe, well-managed and aesthetically pleasing trees which fulfil the desired purpose assigned to them by their owners. It seeks to mimic natural processes, but in a healthier and safer manner (for example, clean cutting off deadwood instead of letting it fall on its own and producing a ragged wound). All pruning should be performed regularly in small doses to minimize stress, as opposed to rare drastic hard pruning. Furthermore, operations should not be performed carelessly or without any real purpose given the risk to the tree during and after pruning. Some good reasons for pruning are described below.

Safety

When it comes to safety of trees, three situations come to mind:

1. *Deadwood*. Any decaying, dying or dead branches or wood should be promptly removed. The risk from such is obvious: they could fall in poor weather onto roads, cars, houses, people, and so on. Deadwood that has already detached and is hung up in a tree is especially dangerous,

[103] I should note: the cost for a copy of BS 3998 now costs in excess of £200. For this reason, I have been unable to examine the guidelines in full. Most of my answer for this question thus consists of reading the provided text and unfortunately relying almost entirely on my own thoughts to construct a suitable answer.

especially to a forestry worker. Pruning away such timber is one of the best reasons for performing surgery on a tree, as the risk to life and property is high. Furthermore, from the tree's perspective clean cuts away from the stem provide less of a risk for pathogenic infections then a ragged breakaway wound since the former is easier for the organism to compartmentalize.

2. *Powerlines*. Any branches or stems growing into powerlines are particularly dangerous in poor weather. Given that a tree can flex in the wind to a much greater degree than the power lines themselves, trees can easily weaken or topple such if they are caught up. Furthermore, from a pure access perspective, trees engulfing utility poles or other such structures can easily inhibit emergency work from being carried out. Pruning in this situation, then, is more of an insurance policy against the potential for work needing to be done, as opposed to a concrete necessity.
3. *Roads*. As previously discussed, there is a legal requirement for trees to be 5.2m clear of all carriageways. The primary reason for this is obvious: cars, lorries and busses may collide with low-hanging branches leading to economic damage or even death. This situation is therefore an extremely good reason to prune a tree, and indeed many go a step further and remove all overhanging branches, even those above 5.2m from the ground, to reduce the change of large debris falling onto the roads.

Other accompanying reasons for pruning include reduce the weight of branches to reduce the dynamic stress on the tree, and reducing wind resistance to minimize the impact of gale force winds and storms on the structural integrity of the timber.

Health

Pruning for health is another obviously valid reason for pruning. It simply involves removing diseased or dying wood to prevent the death of the tree and, in some cases, preventing the spread of the contaminant. Snapped, rotten or broken branches can also be smoothly cut lower down to encourage CODIT and inhibit the entry of wood-decaying organisms. Tools used to work on disease trees should also be sterilized before being used on healthy wood.



Figure 87: A extremely unnatural shape!

Aesthetics

Pruning for aesthetics involves attempts to improve or otherwise return a tree to in natural balanced state. In some case this goes hand in hand with increased flower or fruit production, and in many cases pruning must be started form a young age to achieve the desired effect – as previously discussed in the section of formative pruning. It must always be remembered that a tree is a living organism, and any

attempts to force it into an unnatural state will eventually be reverted over time, at perhaps some great detriment. Trees will often grow out of any shaping unless it falls within their normal state of affairs.

This being said, if one is willing to spare the expense of frequent maintenance, then unnatural forms are more than workable. For example, topiary is an extreme form of pruning which forces an extremely humanmade shape upon a tree, but when maintained it can produce an aesthetically pleasing organism (Figure 87: A extremely unnatural shape!).

The Guidelines

One of the key parts of the BS 3998 guidelines involves the method used to make a cut. In reality it is fairly simple, although mistakes can have disastrous consequences.

To cut a branch, first locate the branch bark ridge. This is found where a branch meets the stem and often takes the appearance of crumpled wood that seems to be growing 'over' the butt of the branch – almost as if it was a hand grabbing the base of it!

Next one makes a stub cut some way up the branch, taking into account tension and compression forces. In most situations, the compression force is on the underside, so a cut is made there first, whilst the tension force is on the upperside and the second cut is made there. This leaves a "stub" – a short section of the branch. It is worth noting now that a stub should never be left as the branch bark ridge, which is what will form the woundwood, would not be able to grow over and close the wound with any great speed given its distance from the stem.

The next goal is thus to create a smooth cut running parallel to the branch bark ridge (Figure 88: Where to Prune on a local tree). It is vitally important that the branch bark ridge is not itself cut. It is this structure that will continue to grow outwards, and what will eventually form woundwood enclosing the cut and preventing decay. If the branch bark ridge is cut then CODIT mechanisms are breached and it allows an entry route for pathogenic organisms into the heartwood of a tree. Furthermore, flush cuts, where the branch is cut back so that it is "flush", or "flat", against the stem should be avoided for a similar reason.



Figure 88: Where to Prune on a local tree

In terms of other guidance, BS 3998 advises against wound dressings. After all there is evidence that such can encourage infections by providing a moist micro-climate within which pathogens can breed effectively. On top of this the standard advices that wood is disposed of properly, whether by chipping, pulping or burning if it is unsuitable for timber. If the wood is free of infection, yet burned, the wood ash can be a valuable fertilizer, otherwise it should be disposed of in the appropriate areas.

A last guidance point comes in the form of timing. I have discussed this previously, but broadly the following is true:

- Conifers and evergreens can be pruned whenever, but preferably in the summer.
- Deciduous trees should be pruned in the winter, although some species can be pruned in spring but it is not advised.
- Do not prune in the autumn, as the mild humid conditions can encourage fungal growth.
- Flowering trees should best be pruned immediately after flowering.

§4.18 – Deadwood, Cavities and Water Pockets.

Deadwood is simply any part of an otherwise living tree that is, as the name suggests, simply dead. It is any branch or shoot that has died - for reasons including pathogenic infection, ring barking, mechanical damage or structural failure - and remains attached to the tree (or, in some cases, unattached but suspended in other branches).

Although still technically still attached in many cases, deadwood can nonetheless pose a severe risk to anything that sits below it should it fall. This is a particular risk in cases where fungi have taken a hold and begun to rot the interior - weakening the otherwise stable structure. Combine this with the fact that deadwood is typically less flexible, will hold onto leaves for longer thus having greater wind

resistance[104], and lacks the necessary biological mechanisms to repair otherwise minor structural faults, means that the risk of detachment grows in line with the weather, and the general size of the branch itself – as does the risk of damage.

In general, the primary reasons for removing deadwood is safety, and this only becomes necessary when the risk of it falling and doing damage, or killing the tree, outweighs the risk to the tree during and after removal. Specific cases where this may be true is when the dead branch is especially large, when it has already become structural weak (for instance, it has snapped), or when it is a vessel for disease which could spread to the rest of the living tree.



Figure 89: Cavity in a Tree

Similarly related to deadwood is cavities (Figure 89: Cavity in a Tree). This is simply any hole or space that exists within a tree's wood that has formed because of rot or, in rarer cases, animals, storms[105] or mechanical damage. When a cavity contains a reservoir of water, it is known as a water pocket.

Treatment for both in the past generally revolved around the idea of filling the cavities to prevent infection, but nowadays the preferred treatment is to remove any dead and rotting timber and then simply leave it for the elements to deal with, and for the tree to implement CODIT by itself. The tree will naturally form and enclose the cavity over time, and any attempts to remove the walls of the cavity simply opens fresh wood to begin to rot. Therefore, it is often the case that doing nothing is better than doing anything at all. In the case of water pockets the water itself may in many scenarios act as a safeguard against further rot given the anaerobic rot-adverse conditions it creates, even though that may seem paradoxical. Any bolts or such that needs securing to the walls should be above the water level as to not encourage rust.

§4.19 – Bracing Techniques and Best Practice

One of the primary reasons for fitting braces and props to trees is to strengthen or combat weaknesses within the tree's structure. Such weaknesses may include:

- Weak bark branch ridges which threaten to break. In this scenario fitting a brace to hold it against the stem will ensure that it's weight is distributed more evenly amongst the tree.

[104] "How to recognize deadwood", The Spruce, https://www.thespruce.com/how-to-recognize-dead-wood-3269556

[105] "Tree Cavities", Save-a-Tree, http://www.savatree.com/tree-cavities.html

- Overly heavy or lopsided branches which may possible snap and fall. Alternatively, they may turn into hazard beams. In this case the brace will once against carry its weight. On the other hand a prop may be used in this situation to "prop" up the branch against the ground.
- Poor primary stem dominance, leading to multiple stems with weak joints competing against each other. Furthermore, given that they each compete with each other, branches emanating from each stem typically grows outwards from the centre[106], leading to an overabundance of weight – and stress – on each trunk. A brace here would serve to restrain the tree and combat the forces that would drive the stems apart, leading to fracturing.
- Support deadwood. Much like the above heavy branch brace, deadwood which it is infeasible or unpractical to remove could be supported against the tree to ensure that it doesn't fall unexpectantly.
- Limit movement of branches[107]. This is primarily a defence against storms dislodging branches. By restricting the movement of branches through bracing one reduces the risk of catastrophic failure.

There is a total of three different types of tree bracing techniques, including propping, and each has its specific use and all should be fitted into sound wood. A common technique involves the use of flexible high-gauge, high-tensile galvanized steel wire. These types of braces allow some limited movement, but in general restrict excessive movement – especially with co-dominant stems – that may cause failure in poor weather or the like. These wires are attached with either screw eye bolts (up to 885kg, in general; Figure 90: Screw Eye Bolt) which are limited to one side of a branch, or eyebolts (up to 10 tonnes; Figure 91: Eyebolt) which are driven through a branch (Figure 92: Example of an Eyebolt in a Tree). All parts of a tree bracing system, especially in multi-part systems such as the aforementioned flexible bracing, should be rated at the same strength to prevent excessive wear on a single component, and all manufacturer recommendations should be followed to the letter.

An alternate type of bracing is, unlike the above, ridged. In this scenario, inflexible steel rods are used instead of flexible wire.

[106] "Tree Cabling and Bracing", Arborilogical, http://www.arborilogical.com/services/cabling-and-bracing/

[107] "Cabling and Bracing", Bartlett Tree Experts, https://www.bartletttree.co.uk/cabling-and-bracing.cfm



Figure 90: Screw Eye Bolt



Figure 91: Eyebolt



Figure 92: Example of an Eyebolt in a Tree

A last type of support is propping. This is exactly what it sounds like – propping up a branch with some form of inflexible rod. In this situation the rods do not typically pierce or damage the wood (Figure 93: Non-damaging Prop), although this is not always the case (eyebolts are then used; Figure 94: Fixed Prop). In either case the base of the support needs to be, obviously, immobile. To manage this the base is typically affixed to a buried concrete block, or similar, which inhibits movement (Figure 95: A prop affixed to a concrete block).

In terms of standards. BS 3998 suggests that all work should be carried out by trained personnel (i.e. with perhaps relevant NPTC Certificates), and that all work should be reviewed at least yearly.



Figure 93: Non-damaging Prop[108]



Figure 94: Fixed Prop[109]



Figure 95: A prop affixed to a concrete block[110]

[108] Via the University of Florida, http://hort.ifas.ufl.edu/woody/propping.shtml

[109] *See* 108

[110] *See*108

§4.2 – Best Practices and Compliance with the Law

§4.21 – HSWA

a.k.a. The Health and Safety at Work Act, 1974

Overview

The HSWA, in summary, outlines the general duties that employers *and* employees – paid or unpaid - have to maintain a safe place of work. It applies to all workplaces up and down the country. Employers must ensure that they maintain a safe place of work and that all workers are trained in their station. Employees must be aware of their environment and work in a safe manner in accordance with the law and company policy.

Key Regulations Relevant to Arboriculture Found in Schedule 3 of the HSWA 1974

4(1) *"Prohibiting the carrying on of any specified activity or the doing of any specified thing except under the authority and in accordance with the terms and conditions of a licence, or except with the consent or approval of a specified authority."*

Implication: This part specifies that all work must be carried out within the remit of the appropriate licenses (i.e. felling licenses).

6(2) *"Restricting the performance of specified functions to persons possessing specified qualifications or experience."*

Implication: All workers should be adequately trained and have experience in the work that they are to undertake, i.e. tree surgeons must have the appropriate qualifications and certificates to ensure that they are competent in their duties. Any contravariance of this jeopardizes the safety of the employee and potentially others, and is thus illegal.

9 *"Imposing requirements with respect to any matter affecting the conditions in which persons work, including in particular such matters as the structural condition and stability of premises, the means of access to and egress from premises, cleanliness, temperature, lighting, ventilation, overcrowding, noise, vibrations, ionising and other radiations, dust and fumes."*

Implication: Employees must be protected from dangerous elements in their work insofar as is possible. This is almost automatic with modern chainsaws which have anti-vibration mounts, exhausts pointing away from the operator, etc. All safety features should be checked before use. The area where work is to take place must have been checked for safety and the work should be carried out in daylight.

10 *"Securing the provision of specified welfare facilities for persons at work, including in particular such things as an adequate water supply, sanitary conveniences, washing and bathing facilities, ambulance and first-aid arrangements, cloakroom accommodation, sitting facilities and refreshment facilities."*

Implication: The main implication of this section is that first aiders should be available, and that all employee should be allowed access to refreshments should they need it. For example, going deep into the woods without water would threaten the health and safety of the

individual, and is thus ill advised. Regular breaks should be schedules to prevent fatigue and exhaustion setting in and undermining the safety of workers.

11 *"Imposing requirements with respect to the provision and use in specified circumstances of protective clothing or equipment, including clothing affording protection against the weather."*

Implication: Appropriate PPE must be provided by the *employer*, and it must be worn where appropriate. Sometimes this is mandatory, such as eye, ear, leg, feet and hand protection when using chainsaws.

A The punishment for contravening the HSWA is *generally* up to 12 months' imprisonment and up to a £20,000 fine, although in some circumstances this can be raised to 2 years and an unlimited fine.

Summery

Although the HSWA is fairly long, it implications could simply be summarized by the employer, or employee, by asking three simple questions:

1. Could the work that I or other are to undertake cause harm? If yes, then ask Q2;
2. Have all precautions against harm be considered and precautions put in place? i.e. has there been an adequate risk assessment? If *no* then a suitable risk assessment should take place and precautions implemented.
3. Are all workers trained and competent in their duties? If *no* then considered additional training, or placing someone who is trained in that given duty.

In addition to this all work should take note of the risk to the public. In arboriculture, for example, one may work on roads. To maintain a safe place of work one must then ensure that adequate signage has been place alongside the road – in accordance with the Roads and Street Work Act, 1991 - and that all precautions have been put in place to limit the risk of an accident.

In addition to this many common-sense rules should be considered. For example, storing equipment safely, ensuring fuel is in appropriate containers, making sure that there are first aid kits available, making sure there is some way to contact the emergency services, ensuring fire extinguishers are available, don't use broken or defective equipment, only use equipment how one is trained (i.e. snedding in line with what is taught in NPTC CS31) and so on. Basically, anything that could cause harm, shouldn't be done or used. The punishments for contravening this are severe, both personally and legally.

The content of HSWA is heavily reliant on, and extended by the content of later regulations. These include, but are not limited to, the Management of Health and Safety at Work Regulations (MHSWR; §4.22), the First Aid at Work Regulations (FAWR; §4.23), the Provisions and Use of Work Equipment Regulations (PUWER; §4.26), the Lifting Operations and Lifting Equipment Regulations (LOLER; §4.25), the Work at Height Regulations (WHR; §4.24), the Manual Handling Operations Regulations (MHOR; §4.28), Control of Substances Hazardous to Health Regulations (COSHH), the Noise at Work Regulations (NWR), the Personal Protective Equipment at Work Regulations (PPE; §4.27) and, finally, the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR; §4.29).

The Act tells us that, simply, people must be protected from harm. Anything which unduly risks that simple tenant contravenes the law.

§4.22 – MHSWR

a.k.a. The Management of Health and Safety at Work Regulation, 1999

Overview

The Management of Health and Safety at Work Regulations, 1999 (MHSWR) go hand in hand with the HSWA of 1974. It simply outlines the duties that employer and employees have to minimize, assess and avoid risks in the workplace. Furthermore, it sets out the guidelines for dealing with risks, in terms of preparation and emergency procedures.

Risk Assessments

A vital component of many workplaces' compliance with MHSWR is a risk assessment. This is simply where the operations to be carried out are evaluated, the risks assessed, and precautions to minimize or avoid such are put in place. For legal matters this is typically recorded as to serve as a physical record that such has been undertaken.

As per the NPTC guidelines, there are five steps to a risk assessment, which can be remembered by the mnemonic IDERR:

- **I**dentify the risks
- **D**etermine who might be harmed and how
- **E**valuate the risks and identify precautions
- **R**ecord your findings and implement them
- **R**eview and update as necessary

Furthermore, emergency contact details should be noted on the form for ease of reference. These include the address of the location of work, the nearest hospital, emergency contact details, grid reference, landowners name, the first aider, the ease of vehicle and helicopter access and so on.

The aim of a risk assessment is to evaluate the risks and see who might be harmed, and then decide on steps to minimize this risk, as well as outlining emergency procedures should something go wrong. Such steps include making sure that workers are trained and aware, and that any aids that can be used are available (i.e. mechanical lifting equipment, etc.). Such assessment should be regularly reviewed should any part of the plan change in any way.

An example of a risk assessment form is found on the opposite page, following on from the below summary.

Beyond this there should be procedures in place for almost all eventualities. I.e. what should happen if there is a fire (Evacuation procedures, for instance), what should occur should there be a crash whilst working on the road, and so on.

There is also a requirement for employees' health to be regularly monitored and assessed to prevent the exacerbation of underlying or developing conditions. An example of this may be that someone who is experiencing acute back pain should not undertake any heavy lifting, lest they are the victim of a flare up that could result in permanent damage.

Summary

Adherence to the MHSWR in general implies adherence to the HSWA. Although there is no legal recourse for *not* following the MHSWRs, the lack of a risk assessment, and appropriate precautions to

risks and the general surveillance of the health of staff, could lead to conviction under the HSWA should something go wrong. At the very least it invalidates insurance policies.

On a more empathic level it is the duty of all employers and employees to ensure that no one is harmed when performing their duties. Strict adherence to company policy and emergency procedures can lead to a marked reduction in the risk to life and limb.

Risk Assessment Form (Example)	
Emergency Information:	
Date:	Time:
Contact Details:	Contact Name:
Address:	Nearest A&E:
First Aider:	Grid Reference:

The Risk	Who might be harmed?	Precautions taken

§4.23 - FAWR

a.k.a. The Health and Safety (First Aid) Regulations, 1981

Overview

The Health and Safety (First Aid) Regulations, 1981, also known as the First Aid at Work regulations (FAWR), sets out the legal responsibility that *all* employees have to maintain first aid facilities – such as a first aid box - and the requirement for there to always be someone present that is trained in its use, should the risk assessment warrant it. In general with serious accidents first aid should always be considered a stop-gap to prevent further injury or death whilst waiting for specialist assistance.

The First Aid Box

Arborists will naturally spend most of their time in unfamiliar locations, often some distance away from a formal first aid facility. For this reason, many will themselves be trained in First Aid (emergency or otherwise) and a First Aid box will be available wherever they go. Although only a guidance, British Standard BS 8599 covers the recommended contents of a first aid box, which are as follows:

Item	*Small*	*Medium*	*Large*
Guidance Leaflet	1	1	1
Medium Sterile Dressing	4	6	8
Large Sterile Dressing	1	2	2
Triangular Dressing	2	3	4
Safety Pins	12	12	24
Eye Dressing	2	3	4
Adhesive Dressings	40	60	100
Sterile Wet Wipes	20	30	40
Microporous Tape	1	1	1
Nitrile Gloves	6	9	12
Face Shield	1	2	3
Foil Blanket	1	2	3
Burn Dressing	1	2	2
Clothing Shears	1	1	1

Conforming Bandage	1	2	2
Finger Dressing	2	3	4

In addition to the above, given the risk of severe and deep cuts that could arise from the use of a chainsaw, many arborists also like to include emergency blood clotting agents and dressings which can help prevent exsanguination.

Besides this the regulations advice that there is someone trained in the use of all the above, and that first aid facilities are available at short notice.

Summery

Adherence to the FAWR is simple: have a first aid box available, and make sure someone is trained to use it. In theory, should there be proper adherence to health and safety procedures and thorough risk assessment carried out, the need for such should be minimal – but things can and do go wrong, and like many things in life and in law it is often better to be prepared for the worst. After all, the worst thing that could happen is that someone gets injured and there is no way to administer medical help before it's too late.

§4.24 - WHR

a.k.a. The Work at Height Regulations, 2005

Overview

The purpose of the Work at Height Regulations (WHR) is to minimize death and injuries from falls. Naturally trees are tall, and so any tree surgeon wishing to work raised from the ground should take it upon themselves to adhere to the WHRs – not only for their safety, but the safety of those on the ground. So, important are the WHR that their influence can be seen within the practical qualification frameworks, whereby they form a crucial element of the assessment.

Key Provisions Relevant to Arboriculture

Provision 6 Outlines that work at height should be avoided wherever possible. In an arboriculture setting this may be difficult, but can be thought of as suggesting that the fewest people required ascend a tree should do so, and that there should be no one unnecessarily climbing through the canopy.

Provision 7 The equipment chosen to assist working at height should be carefully selected and appropriate for the task at hand. It should be able to carry the weight intended for it, and shouldn't have any structural defects.

Provision 8 Equipment should include a fall protection system. This should serve as a last line of defence should there be a disaster when climbing.

Provision 10 Objects (such as branches) should not be allowed to fall, and where they need to every reasonable step should be taken to avoid it falling upon any person or object

on the ground. All objects should be stored in such a way as not to be unstable and liable to fall or roll over, thus causing injury or damage to property.

Provision 11 Where it is reasonable to assume that there will be falling objects (i.e. branches) then every step possible should be taken to ensure that no unauthorized individual enters the work area. This may include the use of signs, rails and banksmen.

Provision 12 All equipment should be regularly checked, and a written log made. For arborists, most climbing equipment also falls under LOLER.

Provision 14 All operators should be competent, and are ultimately responsible for theirs and others safety.

Beyond this the schedules outline the various industry good practice that can best be summarized as simply saying "Everyone working at height should be competently trained." For arborists, this means formal practical qualifications in aerial tree works. With NPTC this includes the CS38, 39 and 40 qualifications, and many others, which teach the user the ins and outs of tree climbing and aerial chainsaw use, and how best to undertake it safely. It could be said that anyone who does not possess these qualifications, or the equivalent, does not and cannot satisfy the requirements of the WHR.

For the tree surgeon, important pieces of equipment include the harness, karabiners, life-lines and slings. All of which should be inspected before every use for signs of wear, and replaced as necessary. Regular more thorough checks should be carried out and a written log kept.

Summery

For an employer, the WHR's most important aspect, besides health and safety, is the requirement for equipment to be fit for purpose. The exact meaning of this will vary according to the piece itself, but in general it means not allowing equipment to fall into a state of disrepair that may jeopardize the safety of the user. i.e. if a life-line rope is frayed and worn then it is probably not suited for carrying a man's weight! On top of this there is a legal and civil requirement for records to be kept of the majority of major checks. The ultimate purpose of such is to provide traceability and accountability should something go catastrophically wrong. Should the worst happen and there is no evidence of adherence to the WHR then the employer, and perhaps the employee, is liable to conviction under HSWA.

Beyond this there is a reasonable expectation that any work at height is both necessary and unavoidable. In general this is obvious: there is no need, after all, to risk life and limb climbing up a tree if there are alternates available – in many cases, however, there is not, and thus great care must be taken to organize a plan to ensure the safety of all involved. Like many of these laws, preparation is key.

§4.25 - LOLER

a.k.a. The Lifting Operations and Lifting Equipment Regulations, 1998

Overview

The Lifting Operations and Lifting Equipment Regulations (LOLER), 1998, covers all equipment that is, unsurprisingly, used to carry weight or lift objects. It sets out the expected inspection frequency, the desire for all equipment to be fit for purpose, for all operators to be competently trained, and for safe working loads to be adhered to. For many piece of equipment use by the tree surgeon there is also the expectation that it adheres to PUWER as well.

Key Provisions Relevant to Arboriculture

Provision 4 All equipment must be strong enough to carry the load intended for it, with a particular regard taken for the joints of the systems. In rope systems, this provision may imply that all equipment has to be fit for purpose and rated to carry the users load, with there being no weak links at any point. For mechanical aids, such as MEWP the stated maximum working load should not be exceed. For both, the systems should be checked before use with a keen eye kept for defects.

Provision 6 All equipment, such as MEWP, should be positioned in such a way as to avoid the load hitting an unintended person. In many cases blocking off unauthorised access to the site is sufficient, although in some cases a banksman may be required.

Provision 7 All lifting equipment should be clearly marked with its safe working load clearly visible. If the equipment is intended to carry persons then this should also be noted, and likewise if it not intended for carrying a person it should be clearly marked to state such.

Provision 8 All lifting operators should only be carried out by competently trained individuals – with the relevant qualifications - properly supervised by an experienced team member, and carried out in according with other relevant regulations such as the HSWA and the WHR.

Provision 9 Equipment should be regularly checked. These checks must be performed before every use at a new site and before using any unfamiliar pieces of equipment. Full inspections should be undertaken every 6 months for equipment which is designed to carry a person, and every 12 months for all other lifting equipment. No equipment should be leave the person responsible for it without the handing over of physical evidence of inspections, such as written logs.

Provision 10 Any defects should be reported immediately to the relevant authority – such as a supervisor or the owner of the system - and the equipment put out of service until it is remedied.

Schedule 1 and the Content of Reports

Under Provision 9 all equipment should have through checks undertaken *at least* every 6 to 12 months. For both legal and civil law purposes a written report should be made of these checks so that there is a log available whereby there can be accountability and traceability should something go wrong. This report must contain all of the following details:

- The name and address of the employer
- The date and time of the new examination
- Address of examination location
- Unique identifiers for the equipment – i.e. serial number – and its date of manufacture
- Date of last examination
- Current safe working load
- Full description of any major defects that could cause harm to individuals
- Full description of any repairs undertaken on major defects
- Full description of any minor defects that have the possibility to evolve into major defects
- Full description of any repairs undertaken to remedy minor defects
- The latest possible date for the next inspection

Once an inspection has been complete and all the above noted then the report should be stored safely and should follow the piece of equipment around.

Summary

Overall LOLER is once again an act of common sense. Don't exceed the recommended load, and check all equipment before use, with more detailed inspections carried out regularly. Ultimately with the range of equipment used in arboriculture – such as the harness' used for climbing as well as MEWP – it is obvious that they should be inspected, lest a major accident occurs. Everyone using such equipment also has a responsibility to protect themselves and to check equipment before they use it, and ensure that that are competently trained and up to the job. From a legal point of view, should anyone be harmed because of non-adherence to LOLER then they are liable for prosecution under HSWA.

§4.26 – PUWER

a.k.a. The Provision and Use of Work Equipment Regulations, 1998

Overview

The general jist of the Provision and Use of Work Equipment Regulations (PUWER) is that all equipment used in the carrying out of work related duties should be fit for purpose, safe to use and that all operators should be competent – often judged by whether they hold the relevant qualifications.

Key Regulations Relevant to Arboriculture Found in Part II of PUWER 1998

Almost the whole of Part II of the 1998 regulations is relevant to arboriculture work. In general, however, the regulation really only applies to chainsaws in day to day work since PPE falls under the PPE regulations as opposed to PUWER. Indeed, if we look at the ten safety features built into modern chainsaws we can see clear evidence that they were influenced by, or were an influence on, the PUWER regulations.

1. *Scabbard.* This covers the chain and helps prevent accidental cutting injuries. This is covered by Section 11, which says that employers must ensure that all dangerous components of machinery are covered. Since it is impossible to cover a chainsaw chain all the time this only applies to when it is stationary and in storage.
2. *Chain Catcher*. This catches the chain should it snap, and prevents severe injury to the operator. This is covered by Section 12(3) which states that there must be protections in place to prevent the ejection or disintegration of any part of the machinery that may lead to an injury – in this case the chain being ejected at high speed.
3. *Throttle Lockout*. This requires a two way, two sided, motion to operate the throttle. The palm must press down the throttle lockout before the fingers can operate the throttle and begin to rev the chain. It prevents the throttle from being accidently pushed inwards – perhaps by an errant branch. Section 15 which covers stop controls is relevent to this safety feature, and it states that there must be a mechanism by which the chain can be brought to a stop. In this case releating the throttle or the lockout will return the chainsaw to idle.
4. *Chain Brake*. This sits at the front of the chainsaw and besides protecting the hand from kickback, it also serves as an immediate and abrupt mechanism by which to stop the chain. Should there be any impact of kickback the Chain Brake will be activate and the sprocket will be prevented from spinning the blade. This is covered by Section 16 of the regulations which concerns emergency stopping mechanisms – in that there needs to be one that functions.

5. *Anti-vibration Mount*. Since a chainsaw is essentially and engine with a blade it thus produces a huge amount of vibration, especially when in use. Chainsaws are thus fitted with anti-vibration mounts which serve to reduce the severity of such. This is not overtly convered by PUWER but can fall under Section 7 which states that an employer has a duty to protect employees against specific risks, which could include vibration injuries. In reality it is probably better covered by HSWA.
6. *Rear Hand Guard*. This further protects the hand from any broken chains, and is thus related to the chain-catcher in number 2 above.
7. *Exhaust Direction*. The exhaust on chainsaws is on the opposite side of the device to the operator. This ensures that no toxic fumes are breathed in directly by the worker and thus protects their lung health. This perhaps falls under Section 12, as seen in number 2 above. In that there needs to be protections from any toxic fumes.
8. *Low Kickback Chain*. Many modern chains utilize low-kickback technology (note: *not* anti-/no-kickback chains) which helps prevent the abrupt and uncontrollable movement of the chainsaw into the path of the operator. This falls under Section 11 of the regulations which states that there must be protections in place to prevent dangerous part of machinery coming into contact with workers. Although there is an inherent risk with chainsaws since the blade cannot be covered, the risk can be reduced through proper training and functional equiptment.
9. *On/Off Switch*. This allows for the chainsaw to be switched off in an emergency, and thus comes under the same section as the Chain Brake; Section 16. It could also come under Section 19 which states that there must be a means by which to halt the source of energy.
10. *Health and Safety Sticker*. This sticker generally provides basic advice and reminders about precautions that should be taken when utilizing a chainsaw. This sticker typical visually indicates the need for PPE, including ear and eye Protection. This falls under Section 24 which suggests that all equipment should carry the appropriate warnings.

Besides this PUWER although required that all operators be trained (Section 9), that there be regular inspections of the equipment (Section 6), and that there should be regular maintenance and upkeep (Section 5).

Summery

Overall PUWER is another common-sense regulation that can be summed up as simply the regulations which indicate the legal responsibility for employers and employees to maintain their work equipment and ensure that it is both functionally and theoretically as safe to use as possible. For example, if *any* of the ten safety features of a chainsaw mentioned above are missing, or operators are not competently trained, then one is in violation of PUWER.

Besides chainsaw this also applies to any other machinery or equipment that is used – whether it be hedge trimmers, powered pole pruners, tractors, and so on – whatever it is they must be fit for purpose and safe to use. PPE falls under the PPE regulations, whilst harnesses and the like fall under the Lifting Operations and Lifting Equipment Regulations (LOLER).

§4.27 – PPER

a.k.a. The Personal Protective Equipment Regulations, 2002

Overview

The Personal Protective Equipment Regulations (PPER) set out the requirements for employees and employers to wear PPE where appropriate. It also dictates the need for PPE to be fit for purpose, for it to be used and maintained properly, and for any defects or damages to be rectified immediately. It also

outlines that the *employer* has a duty to provide PPE to their employees. In a broad sense, PPE is a last line of defence against injury, but it is still just as vitally important as PUWER, LOLER, etc in preventing serious injury or death when things go wrong.

British Standards

As far as provision and regulation go, the PPER is expansive and bulky. For that reason it is often better to examine its implications from "the other side", so to speak, and look at what the current standards for PPE are since they are directly derived from the PPER. In general, there are numerous pieces of equipment that a tree surgeon should wear. These and the relevant British Standards are shown below. For reference, the type of material used is often referred to as Class 0, 1, 2 or 3 – depending upon what speed chain it can stop in time. Class 0 can stop a 36mph chain, Class 1: 45mph, Class 2: 54mph and Class 3: 63mph. The material works by getting wrapped around the sprocket and jamming the chain.

Hand	BS EN 381-7	Chainsaw gloves should protect the hand from not only the chain, but also any thorny or rough surfaces, as well as the wet, cold and any vibrations. They should provide grip and comfort, besides merely protecting the hand. Most gloves are class 0, with some being class 1. Classes above this are often too thick to be used in gloves. Traditionally only the left hand had protection, although nowadays you can easily obtain protection on both hand.
Ears	BS EN 352	Naturally loud (up to 115dB), ear protection should always be utilized when using a chainsaw. Ear protection should cover the whole ear and sit firm against the face, as well as providing decent level of noise reduction.
Feet	BS EN ISO 17249	Chainsaw boots range in protection from class 1 to 3, and can be considerably bulky on the end of that scale. Boots should provide decent grip and tread, with adequate water and cold protection where required. A toe-cap is often included to guard against crushing injuries – such as falling branches. Typically this toe-cap is made of steel, which also protects against chainsaws, although in cheaper variants it can be made of composites.
Head	BS EN 397 BS EN 12492	A helmet should protect against falling debris such as deadwood and be firmly affixed to the head. Climbing helmets should offer collision protection as well as a chinstrap to prevent it falling off.
Eyes	BS EN 1731	A mesh visor, at the very least, should be warn to prevent flying debris from contacting the face and especially the eyes. It should be easy to see through whilst offering decent protection from branches, sawdust, and so on.
Legs	BS EN 381-5	A chainsaw can sometimes be in close proximity to the legs, and so there is a requirement for trousers to be worn that protect against cutting injuries, as well as providing a barrier to the outside elements such as the cold or rain.

Chainsaw trousers whilst being rated Class 0, 1, 2 or 3, also are sold according to the direction of the protection. Type A trousers only have protection on the front of the legs and are suitable for ground-work, whilst Type C trousers have all-round protection and are best used for aerial work. In reality, however, the weather conditions should be taken into account, as Type C trousers are hotter and bulkier then Type A trousers, and this is exacerbated if they are of a high class.

Surprisingly there is no requirement to wear torso protection, and so it is entirely optional.

Summery

PPE may be the last line of defence, but if all else fails it might just simply be what saves your life! All operators must be trained in the use and upkeep of their PPE, and any defects or so on should be rectified immediately. The implications of not wearing PPE can range from invalidated insurance to imprisonment under the PPER framework. Common-sense once again applies – i.e. if the trousers are torn, then they need replacing; if there are rose bushes in the working area, suitable gloves should be worn, and so on.

§4.28 – MHR

a.k.a. Manual Handling Regulations, 1992

Overview

The Manual Handling Regulations, 1992, sets out guidelines and requirements for employers and employees to ensure that all manual handling practices – that is, lifting, moving, pushing, pulling, throwing, and so on, of an object – are performed in the most health-conscious way possible. It also sets out the desire for all individuals involved to be trained to a competent level, and for all manual handling to be avoided except where necessary.

Relevance to Arboriculture

Where and when the MHR come into play is a matter for common sense. Although it is set out in absolute detail in the regulations, in general any time that force or exertion must be utilized to move, shunt, push, carry, lift, lower, roll, or pull an object then it is a safe bet that the MHR come into play.

When they do a thorough risk assessment should be carried out. This should consider the size of the object (i.e. can both sides be held), the shape of the object (i.e. any sharp edges), the fluidity and stability of the object (i.e. will the weight shift when moving), the surface one is walking upon (i.e. is it on a hill, is it slippery, etc.) and other various evaluations that are typical of any risk assessment – for example, how good are the lighting conditions. Once this has all been taken into account then one should first look for manual handling aids before progressing onto directly handling objects.

The relevance to arboriculture is perhaps obvious: wood. Wood is heavy and if lifted in an improper manner – i.e. with the back and not the legs – then over time it can cause back pain and fatigue, the former of which can be permeant enough to be considered disabling. Some things to consider, and some remedies, are:

Weight Wood is naturally heavy. For this reason, it is often useful to employ the aid of lifting aids, such as lifting tongs, levers, pullies and winches. Furthermore, sensible carrying technique can help minimize effort – for example by rolling a log as opposed to pulling it.

Grip In poor conditions wood can be extremely wet and slippery. This presents a risk of dropping the load, perhaps causing injury. The simple solution to this is to wear gloves which provide additional grip.

Shape Snedded or unsnedded wood can perhaps be of an odd shape which can complicate the lifting manoeuvre. In this scenario it is oftentimes best to request assistance.

Footing When working in a forestry environment the footing underneath can be unstable or chaotic. Proper preparation can minimize this risk, although in ideal circumstances one should also be able to see where they are going.

When lifting is required, proper technique should be applied. In a nutshell this involved lifting with your knees with your back straight, with the load held in a firm grip close to the body. All employees should be trained, perhaps formally, should their work involve a great deal of lifting, or if it may jeopardize their safety. In an arboriculture setting most formal qualifications, such as those offered by NPTC and Lantra, have made the practice and awareness of proper lifting techniques a mandatory part of the syllabus.

Summery

As with most regulation, common sense reigns supreme. A proper risk assessment coupled with the availability of relevant lifting aids and proper training should, in theory, minimize the risk of serious harm that can result because of improper lifting techniques.

§4.291 – RIDDOR

a.k.a. The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations

Overview

All accidents, injuries, near-misses and serious diseases must be reported to the Health and Safety Executive (HSE) as soon as is possible. There is ultimately a massive range of diseases and disorders that are covered by the act, but only a handful are relevant to arborists.

Key Regulations from the 2013 Statute which expands on the 1995 Statute, for Arboriculture

Regulation 4(1) Reportable (acute) non-fatal injuries "*for workers*" include:

(a) "*any bone fracture … other than to a finger, thumb or toe*"
(b) "*amputation of an arm, hand, finger, thumb, leg, foot or toe*"
(c) "*any injury … likely to cause permanent blinding or reduction in sight in one or both eyes*"
(d) "*any crush injury to the head or torso causing damage to the brain or internal organs in the chest or abdomen*"
(e) "*any burn injury (including scalding) which* – (i) *covers more than 10% of the whole body's … or* (ii) *causes significant damage to the eyes, respiratory system or other vital organs*"
(f) "*scalping requiring hospital treatment*"
(g) "*loss of consciousness caused by head injury or asphyxia*"
(h) "*any other injury arising from working in an enclosed space which* – (i) *leads to hypothermia or heat-induced illness; or* (ii) *requires resuscitation or admittance to hospital for more than 24 hours*"

Regulation 4(2) Besides those injuries found in Regulation 4(1), any event "*where any person at work is incapacitated … for more than seven consecutive days*" must be reported within 15 days.

Regulation 5(a) Reportable non-fatal injuries "*for non-workers*" include:

"*an injury, and that person is taken from the site of the accident to a hospital for treatment*"

Regulation 6 Reports must be filed for all the following circumstances:

(1) "*Where any person dies as a result of a work-related accident"*
(2) "*Where any person dies as a result of occupational exposure to a biological agent"* (i.e. a disease)
(3) "*Where an employee has suffered an injury reportable under regulation 4 which is a cause of his death within one year of the date of the accident"*

Regulation 7 "*Where there is a dangerous occurrence*" it must be reported promptly.

Regulation 8 Reportable occupational (chronic) diseases for workers include:

(a) "*Carpal Tunnel Syndrome*" from the use of "*percussive or vibrating tool*"
(b) "*cramp in the hand or forearm*" from repetitive movements
(c) "*occupational dermatitis*" where it could reasonably be assumed to be caused by an at-work exposure to an irritant
(d) "*Hand Arm Vibration Syndrome"*
(e) "*occupational asthma*"
(f) "*tendonitis or tenosynovitis in the hand or forearm*"

Regulation 9 Reportable serious diseases for workers include:

(1) *"any cancer attributed to an occupational exposure to a known human carcinogen or mutagen (including ionising radiation)"*
(2) *"any disease attributed to an occupational exposure to a biological agent"*

Expanding on this: what is and isn't reportable?

It is all well and good stating the above, but bar for the explanation of serious diseases and occupational injuries, there is very little detail as to the specifics within the regulations themselves. For example, tetanus is a risk for forestry workers, but the question is: is it reportable? Likewise, what counts as a "*dangerous occurrence*" and what is merely just an accident? Thankfully the regulations are expanded upon in the schedules that follow it – mainly within the 1995 act. Thus, for arborists, the following potentially likely occurrences are reportable:

Dangerous Occurrences	Diseases
Lifting equipment collapse or overturning	Subcutaneous cellulitis (From infected cuts)
Any contact with an electricity line	Traumatic inflammation of the tendons
Explosions or fire	
Any structural collapse	Anthrax (From infected fields)
Spillage of 10kg+ of flammable liquids	Extrinsic alveolitis (From pollutants or sawdust)
	Hepatitis (From contact with infected material)
	Legionella (From soil)
	Leptospirosis (From working around infected animals)
	Lyme disease (From ticks in rural areas)
	Occupational dermatitis (From irritants)
	Tetanus (From soil and manure)
	Almost all major poisonings

Reporting – How to do it?

In the past, RIDDOR reports could be sent in via snail mail, but today all reports must be filled online which allows it rapid entrance into their databases and a case file to be opened. For the reporting of major injuries and death a telephone service is also provided at 0345 300 9923. All reports must be filed within 10 days - except those relating to causing the injured part to be out of work for 7 days or more, in which case it must be reported within 15 days.

The report itself should contain all the basic details, such as the name of the injured party, the date, time and location of the incident, and so on, alongside a summary of the events that had unfolded before and after the accident.

For minor injuries, it is often enough to filed a report in an accident book for future reference.

Summery

Ignoring construction, arboriculture is one of the most dangerous industries to work within and so there is a multitude of ways that things can go drastically wrong. Any injury or infection that is work related,

or likely to have been work related, should be reported to the HSE via RIDDOR. In general reportable incidences are obvious, as in the case of amputation, or unusual, as in the case of anthrax or tetanus – but really any incident that leads to, or had the potential to lead to, disfigurement, dismemberment, disability or death *must* be reported to the HSE.

Two punishments arise from failure to report incidents. The first is legal, and takes the form of an potentially unlimited fine. The second is civil, and involved the payment of compensation to the injured or their families – although this is only particularly likely if the incident also arose from a violation of the HSWA.

§4.292 – WCA

a.k.a. The Wildlife and Countryside Act, 1981

Overview

The Wildlife and Countryside Act, 1981, (WCA) outlines a range of protections for wild flora and fauna. In essence it describes that it is illegal to uproot, kill or take any wild flora listed in the schedule, and it is prohibited to kill, main, injury, disturb or destroy the habitat of any protected animal species – and this includes the sale or commercialization of any animal or products derived therefrom, including eggs. It also prohibits the sale of invasive species.

The Schedules

Like many acts, the WCA is quite a bulky document. Of particular importance is the list of protected species. For most it is impractical to memorize the whole list (although that's not to say we shouldn't) so there are some broad generalizations that can be made.

- Any bird that is found to be nesting, or whatnot, should be assumed to be protected unless positively identifies as an unprotected species. This may involve the halting of any planned work, but it is a necessary outcome. Should trees or whatnot be felled and they are later found to be home to a protected species then the logger is protected under law if it can be proved that it was impossible to know that such was there. Bats, although not birds, are also protected.
- Land animals. There are very few major land animals in Great Britain so the list is shorter and more easily remembered. In a broad sense, most animals that one is likely to come across are protected, and this includes badgers, wild cats, hedgehogs, red squirrels, shrews, dormice, deer and otters. Rabbits and hares are allowed to be taken, but not poached.
- The list of protected plants is also long, and it is worth becoming acquainted with them as they are more likely to be stumbled across in day to day forestry work. In general if one happens across an unusual plant it is worth stopping for a movement and attempting to identify such before continuing.

Overview

The ultimate goal of WCA is to protect Britain's native species and natural beauty, and it is an aim that we should all aspire to. A good rule of thumb when undertaking work around such is to not harm anything unnecessarily, whether it is protected or not. In most cases this would save one from the wrath of the law, but in a more empathic sense it ensures that out forests and hedgerows, and the like, are full of a diverse range of wildlife.

§4.293 – AFAG

a.k.a. The Arboriculture and Forestry Advisory Group

The AFAG's primary goal is to ensure that there is guidance provided concerning industry good practice, as well as making sure that all workers are trained to the same standard. In the past they provided a range of leaflets outlining the safety aspects of a wide range of tasks. Now this duty has fallen to the Forestry Industry Safety Accord (FISA), but the general gist of the content is identical to the AFAG leaflets. These can be purchased from FISA at some cost (Approximately £4 per a set of ten leaflets). There primary use, if one is aware of all the acts and regulations outlined above, is to provide a handy quick reference guide to the many provisions that need to be followed rigorously.

§ 5

Tree Inspections and Laws Applied to Trees

§5.1 – Undertaking Safety Inspections

§5.11 – Tree Survey Risk Headers

There are a wide range of headers under which data can be collected when performing a tree survey, especially when they relate to the risks posed by such. Some headings which can be used to classify observations and make a sound judgement to the risk posed by a given tree include:

- Any structural faults. This includes splits, cracks, rot, leaning or so on. These are essentially a "risk factor". This is because without some form of fault – inherent or otherwise – it is unlikely that a tree would fail or pose a hazard.
- Value and targets. In essence tree surveys are a science of probability, and part of the skill of tree surveying is weighing up the *chance* that a tree will fail and the *damage* that will be caused if such occurs. For example, a tree with a vertical split down a weak fork poses a greater threat in an urban environment compared with if it was sat in the middle of a field all alone. In the former the damage that could be caused is greater, and thus it poses a greater hazard then the latter. There is also a need to evaluate the value of a tree. A highly valuable tree might have more careful work performed upon it compared to a low value tree that may simply be felled if it presents any sort of hazard.

It is the combination of these two factors that determines the ultimate risk posed by a tree – thus collecting data that falls under both headers allows for a sound judgement of any hazard posed.

§5.12 – Tree Survey

In the following pages I've performed a small survey on a tree found at a local country park (Figure 96: A local tree - Figure 100: Evidence of historic wounds and CODIT).



Figure 96: A local tree



Figure 97: Strong lean with major buttresses



Figure 98: Presence of rot in the trunk



Figure 99: Potential rot in the BBR of a major fork



Figure 100: Evidence of historic wounds and CODIT

A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas

TREE HAZARD EVALUATION FORM 2nd Edition

Site/Address: _____

Map/Location: _____

Owner: public _____ private _____ unknown _____ other _____

Date: _____ Inspector: _____

Date of last inspection: _____

HAZARD RATING:

_____ + _____ + _____ = _____

Failure Potential + Size of part + Target Rating = Hazard Rating

_____ Immediate action needed

_____ Needs further inspection

_____ Dead tree

TREE CHARACTERISTICS

Tree #: _____ **Species:** _____

DBH: _____ **# of trunks:** _____ **Height:** _____ **Spread:** _____

Form: ☐ generally symmetric ☐ minor asymmetry ☐ major asymmetry ☐ stump sprout ☐ stag-headed

Crown class: ☐ dominant ☐ co-dominant ☐ intermediate ☐ suppressed

Live crown ratio: _____ % **Age class:** ☐ young ☐ semi-mature ☐ mature ☐ over-mature/senescent

Pruning history: ☐ crown cleaned ☐ excessively thinned ☐ topped ☐ crown raised ☐ pollarded ☐ crown reduced ☐ flush cuts ☐ cabled/braced ☐ none ☐ multiple pruning events Approx. dates: _____

Special Value: ☐ specimen ☐ heritage/historic ☐ wildlife ☐ unusual ☐ street tree ☐ screen ☐ shade ☐ indigenous ☐ protected by gov. agency

TREE HEALTH

Foliage color: ☐ normal ☐ chlorotic ☐ necrotic **Epicormics?** Y N

Foliage density: ☐ normal ☐ sparse **Leaf size:** ☐ normal ☐ small

Annual shoot growth: ☐ excellent ☐ average ☐ poor **Twig Dieback?** Y N

Woundwood development: ☐ excellent ☐ average ☐ poor ☐ none

Vigor class: ☐ excellent ☐ average ☐ fair ☐ poor

Growth obstructions:

☐ stakes ☐ wire/ties ☐ signs ☐ cables

☐ curb/pavement ☐ guards

☐ other _____

Major pests/diseases: _____

SITE CONDITIONS

Site Character: ☐ residence ☐ commercial ☐ industrial ☐ park ☐ open space ☐ natural ☐ woodland\forest

Landscape type: ☐ parkway ☐ raised bed ☐ container ☐ mound ☐ lawn ☐ shrub border ☐ wind break

Irrigation: ☐ none ☐ adequate ☐ inadequate ☐ excessive ☐ trunk wettled

Recent site disturbance? Y N ☐ construction ☐ soil disturbance ☐ grade change ☐ line clearing ☐ site clearing

% dripline paved:	0%	10-25%	25-50%	50-75%	75-100%	**Pavement lifted?** Y N
% dripline w/ fill soil:	0%	10-25%	25-50%	50-75%	75-100%	
% dripline grade lowered:	0%	10-25%	25-50%	50-75%	75-100%	

Soil problems: ☐ drainage ☐ shallow ☐ compacted ☐ droughty ☐ saline ☐ alkaline ☐ acidic ☐ small volume ☐ disease center ☐ history of fail ☐ clay ☐ expansive ☐ slope _____° aspect: _____

Obstructions: ☐ lights ☐ signage ☐ line-of-sight ☐ view ☐ overhead lines ☐ underground utilities ☐ traffic ☐ adjacent veg. ☐ _____

Exposure to wind: ☐ single tree ☐ below canopy ☐ above canopy ☐ recently exposed ☐ windward, canopy edge ☐ area prone to windthrow

Prevailing wind direction: _____ Occurrence of snow/ice storms ☐ never ☐ seldom ☐ regularly

TARGET

Use Under Tree: ☐ building ☐ parking ☐ traffic ☐ pedestrian ☐ recreation ☐ landscape ☐ hardscape ☐ small features ☐ utility lines

Can target be moved? Y N **Can use be restricted?** Y N

Occupancy: ☐ occasional use ☐ intermittent use ☐ frequent use ☐ constant use

The International Society of Arboriculture assumes no responsibility for conclusions or recommendations derived from use of this form.

TREE DEFECTS

ROOT DEFECTS:

Suspect root rot: Y N **Mushroom/conk/bracket present:** Y N **ID:** _____

Exposed roots: ☐ severe ☐ moderate ☐ low **Undermined:** ☐ severe ☐ moderate ☐ low

Root pruned: _____ distance from trunk **Root area affected:** _____% **Buttress wounded:** Y N **When:** _____

Restricted root area: ☐ severe ☐ moderate ☐ low **Potential for root failure:** ☐ severe ☐ moderate ☐ low

LEAN: _____ deg. from vertical ☐ natural ☐ unnatural ☐ self-corrected **Soil heaving:** Y N

Decay in plane of lean: Y N **Roots broken** Y N **Soil cracking:** Y N

Compounding factors: _____ **Lean severity:** ☐ severe ☐ moderate ☐ low

CROWN DEFECTS: Indicate presence of individual defects and rate their severity (s = severe, m = moderate, l = low)

DEFECT	ROOT CROWN	TRUNK	SCAFFOLDS	BRANCHES
Poor taper				
Bow, sweep				
Codominants/forks				
Multiple attachments				
Included bark				
Excessive end weight				
Cracks/splits				
Hangers				
Girdling				
Wounds/seam				
Decay				
Cavity				
Conks/mushrooms/bracket				
Bleeding/sap flow				
Loose/cracked bark				
Nesting hole/bee hive				
Deadwood/stubs				
Borers/termites/ants				
Cankers/galls/burls				
Previous failure				

HAZARD RATING

Tree part most likely to fail: _____

Inspection period: _____ annual _____ biannual _____ other _____

Failure Potential + Size of Part + Target Rating = Hazard Rating

_____ + _____ + _____ = _____

Failure potential: 1 - low; 2 - medium; 3 - high; 4 - severe

Size of part: 1 - <6″ (15 cm); 2 - 6-18″ (15-45 cm); 3 - 18-30″ (45-75 cm); 4 - >30″ (75 cm)

Target rating: 1 - occasional use; 2 intermittent use; 3 - frequent use; 4 - constant use

HAZARD ABATEMENT

Prune: ☐ remove defective part ☐ reduce end weight ☐ crown clean ☐ thin ☐ raise canopy ☐ crown reduce ☐ restructure ☐ shape

Cable/Brace: _____ **Inspect further:** ☐ root crown ☐ decay ☐ aerial ☐ monitor

Remove tree: Y N **Replace?** Y N **Move target:** Y N **Other:** _____

Effect on adjacent trees: ☐ none ☐ evaluate

Notification: ☐ owner ☐ manager ☐ governing agency **Date:** _____

COMMENTS

The purpose of this much of this information involved the identifying factors surrounding the tree (such as species, height, crown spread, diameter, age, and so on) which allows for it to be easily identified in the future, and so work does not accidently occur on the wrong tree. The rest of the information is essentially a risk assessment which concludes with a recommendation of work and a timescale within which such should be carried out.

§5.13 – Systematic and Diagnostic Inspections

There are many reasons why a tree survey needs to be performed in a systematic manner, these may include:

1. *Legal responsibilities*. If a tree survey is performed haphazardly and without care or attention then any losses resulting from the failure of a tree could lead to a claim of negligence being placed upon the surveyor. i.e. if a hazard beam is not spotted and a branch falls onto a house as a result, then the surveyor could be claimed to be negligent in his duties.
2. *Value*. The value of a tree can be directly influenced by the result of a tree survey. For this reason, care should be taken to ensure that it is performed correctly and coherently. Surveys must thus be undertaken systematically to ensure that a tree is no over or under values as a result. For instance, if a tree is found to have no defect but it does, then it may be overvalued.
3. *Repetition.* BS 3998 recommends that tree surveys are carried out regularly. For a given area, then, surveys need to be systematic to ensure that the correct trees are examined and at the correct time.
4. *Developing issues*. If a survey is not undertaken systematically then small issues can be overlooked or ignored, intentionally or unintentionally, and this may jeopardize the health for the tree over the time period until the next survey. For example some fungal infections can spread rapidly and if the first signs or infection are overlooked then whole colonies of tree can be wiped out rapidly.
5. *Risk*. One of the most obvious reasons for undertaking tree surveys in a systematic manner is to properly evaluate the risk to surrounding property and people. If one area is neglected – perhaps the use of diagnostic tools – then a tree may not properly be asses and there may be a risk to others as a result.

Diagnostically tree surveys should be just that: diagnoses of problems. By approaching a survey with a rigid diagnostic strategy in place all areas of the tree, and all methods, can be brought together in a simple and coherent conclusion. For example, one may start with visual observations and follow this up with the use of diagnostic tools to aid in interpreting the initial evidence. The goal should always be to *diagnose* problems, and all activities should be means to that end.

In terms of common problems that may be encountered, all the usual issues arise. These may include the obvious: such as dead branches, hazard beams, evidence of decay or rot and weak branch bark ridges – and the not so obvious, such as damage to the root zone caused by compaction or mechanical injury and the first stages of pathogenic infection.

§5.2 – Recommendations Following Inspections



Figure 101: Tree with a Weak Fork

Figure 101: Tree with a Weak Fork, shows a tree sitting on a slight embankment whereby two primary stems join weakly at the base – also known as forking. The probable recommendation for work that might need to be applied to the tree is the use of a bracing system to prevent catastrophic failure of the joint. In terms of the consequences of such on future management needs we would note, as aforementioned in the previous lesson, that the bracing would need to be regularly inspected - perhaps yearly – which would incur some cost. Furthermore, the above tree is situated within a country park and so there may be an argument for *not* bracing the tree unless absolutely necessary due to its visual ugliness. However, given the fact that it leans towards a well-trodden path it may be the case that safety requires such to be implemented anyway – although it may simply be placed higher in the canopy. This being said, I saw no evidence that it was at any particular risk of failure. Similar examples can be found with the below figures (Figure 102: Heavily Leaning Forked Tree; Figure 103: Semi-Mature Forked Tree that may Develop into a Hazard)



Figure 102: Heavily Leaning Forked Tree



Figure 103: Semi-Mature Forked Tree that may Develop into a Hazard

§5.22 – Implementation for a Named Tree

§5.3 – Common Law Applied to Trees

§5.31 – The Definition of Common Law

Standing in contrast with Statute Law, Common Law is any law or regulation that "has been developed on the basis of preceding rulings by judges"[111]. This is to say that any case concerning trees which has been brought to court, and has been ruled on by a judge, forms the basis of common law.

§5.32 – The Law in Relation to Overhanging Branches and Roots

When it comes tour gardens and houses, the boundaries of our land extend upwards from the top of the fence, wall or house. This is to say that we exist in almost imaginary boundaries which extend above and beyond our physical boundaries as per the deed. For this reason, anything that is within these boundaries can be dealt with by oneself, without needing the permission on the owner of the offending object itself.



Figure 104: An Overhanging Tree that has been Cut Back

In relation to trees, this implies that any branches that happen to be overhanging into your garden can be cut back to the boundary line without needing the permission of the tree's owner. Any further then this then it is deemed to be an act of trespass[112] (Figure 104: An Overhanging Tree that has been Cut Back). It is worth noting that even if 99% of a tree's crown is in your garden, the tree still belongs to the person within whom garden it grows – where the trunk and base are located – unless the deed says otherwise.

There are a few little caveats to the above, however. The first is that the tree's branches, fruit and leaves still, technically, belong to the tree's owner – whether they are overhanging into your garden or not. For this reason, they must be offered to be returned after cutting[113]. A caveat to this caveat is that they cannot simply be dumped into the owners garden without permission, or else this is considered fly tipping.

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[111] "Common Law vs Statute Law", Diffen, http://www.diffen.com/difference/Common_Law_vs_Statutory_Law

[112] "Pruning a Neighbours Tree", West Berkshire Council, http://info.westberks.gov.uk/CHttpHandler.ashx?id=22464&p=0

[113] "Trees", Garden Law, http://www.gardenlaw.co.uk/trees.html

In addition to this any die-back or death causes as a result of pruning by oneself is considered criminal damage, and for this reason it is always advisable to come to an agreement with the offending neighbour before any work takes place. If there is pre-existing damage cause by the tree, then the owner is liable to pay any damages, however.

In relation to roots, the same applies[114]. If they are in your land, then you have the right to prune them back to the boundary (Figure 105: Root Removal Operations). This is particularly risky however given the importance of roots to a tree's health, and therefore a qualified arborist should be consulted beforehand to ensure that there is no room for one to be liable for criminal damage to the tree[115]. Given root's more destructive nature, however, it may be the owner who is liable to paying damages caused by encroaching roots damaging property.



Figure 105: Root Removal Operations

§5.33 – The Law in Relation to Dangerous Trees

The onus is on the owner of the three to sort out, and deal with, dangerous trees. Whether this danger is as a result of storm damage, rot, pest infestation, or so on – if there is a hazard present then the owner of the tree has a legal obligation to deal with the issue promptly. Should any actual damages be realised through whatever means – for example by deadwood falling onto property – then the owner is liable to pay any damages that arise from such[116].

In practice, there is a standard line of escalating action that needs to be taken should a dangerous tree be identified by oneself. The first step is to recognize the danger (Figure 106: The Onus is on the Tree's

[114] "What to do about a neighbour's overhanging tree branch", Saga, https://www.saga.co.uk/magazine/home-garden/gardening/advice-tips/what-to-do-about-a-neighbours-overhanging-tree

[115] "Removal of Tree Roots", InBrief, http://www.inbrief.co.uk/neighbour-disputes/removal-of-tree-roots/

[116] "Problems with Neighbours Trees", Medway Council, http://www.medway.gov.uk/planningandbuilding/treemanagement/problemswithneighbourstree.aspx

Owner to Remedy this Situation), and evaluate who might be harmed, and what might be damaged, It might be useful at this stage to begin to put together a written record of ones observations, which should really include images of the offending tree.

The next step is to contact the tree's owner to make them aware of the danger to life or property that their tree is causing. This passes the buck onto them, so to speak, and the onus is now on them to arrange remedial action – since if any damage does arise, and they were made aware of the risk, then they could be judged to be negligent in court.



Figure 106: The Onus is on the Tree's Owner to Remedy this Situation

Likely the owner will employ the services of a professional tree surveyor or tree surgeon to evaluate and fix the danger. If the professional concludes that the tree is safe, and it then causes damage as a result of something that has been noted, then the professional themselves is now liable to face charges of negligence. Any recommendations from the surveyor should be enacted by the landowner else, once again, they could be seen as being negligent in their duties of care should something actually go wrong.

If the landowner chooses to take no action whatsoever then one can begin to get in contact with the council or a mediator to arrange for legal proceeding to begin. The ultimate result of such may be an order to enact remedial action or else face civil or legal charges of negligence.

As previously mentioned, the fruit from trees belong to the tree's owner. Indeed, the tree's owner has a duty to ensure that it is kept under control. For as long as such poisonous trees are kept confined to the owner's boundary then there is likely to be little risk of damage, but should toxic fruit be eaten by livestock or people, who subsequently fall ill or die, on their own land (that is, the poisonous fruit has fallen onto land not belonging to the owner of the tree), then the tree's owner is liable to pay damages as it could be argued that it was not kept under control. In the same situation, however, if the livestock or people trespass on the tree owner's land and then consequently fall ill or die from ingesting its fruits then the tree's answer is not liable to pay damages. It is on the individual to prevent themselves or their livestock from trespassing. This, however, is only true where the tree's answer is not responsible for the boundary fencing, or similar. If they are responsible for such, then it is their duty to ensure that livestock cannot enter their land.



Figure 107: Taxus baccata (Yew) fruit

The classic case that this arises from is Erskine v Adeane in 1873, concerning cattle and yew trees. In this case Erskine's cattle died from grazing on the fruits of Adeane's Yew tree (Figure 107: Taxus baccata (Yew) fruit). In the end Erskine's claim was rejected, as it was assessed that although Adeane's Yew tree over hanged his land, it was the duty of Erskine to ensure that it was adequately fenced off, and livestock prevented from grazing thereupon. This case primarily involved the knowledge that Erskine possessed before he moved into his at that time present location – i.e. that there was poisonous trees overhanging the land. Should it have been the other way around, with Erskine moving in and *then* a Yew tree being planted which caused damage, then it is likely that Adeane would have been liable. Ultimately, however, this case boils down to who was responsible for maintaining the boundary which prevented cattle from grazing on the Yew's fruits[117]. Likewise, in modern times a farmer, or similar,

[117] "Arboriculture Case Law", Arboriculture.Wordpress, https://arboriculture.wordpress.com/2016/05/16/uk-case-law-and-poisonous-trees/

who owns both a poisonous tree and the fence that inhibits livestock from grazing upon in, is responsible for any damages that it causes on another's land.

§5.35 – The Law in Relation to the Right to Light

A homeowners right to light is enshrined in the fairly ancient *Prescription Act 1832*. In provision 3 of this act it states that "When the access and use of light to and for any dwelling house, workshop, or other building shall have been actually enjoyed therewith for the full period of twenty years without interruption, the right thereto shall be deemed absolute and indefeasible,"[118] This is to say that should a homeowner have lived within their house for 20 years then any encroachment on the light that filters down to into the house is deemed to be in violation of the act.

Practically this means that any long-standing occupant to a house has the right to remove or trim any tree that reduced the volume of light entering their house. In general, it is assumed that the right to light means that at least half of a room should be lit by natural light[119].

§5.4 – Statute Law Applied to Trees

§5.41 – The Definition of Statute Law

In contrast to common law, which involves precedents set by judge's rulings on laws, statute laws are any laws which are mandated by an act of parliament. This is to say that legally statute law is the "official" laws of the land, and they set out guidelines and punishments for enforcing such laws in a criminal court, as opposed to the mostly civil courts of common law. An example of a statute law is that of Tree Preservation Orders of which violations can result in hefty fines – payable to the government – and potentially imprisonment. For reference, it is unlikely that one will be punished with imprisonment or fines (except for liability damages payable to the defendant) for something related to common law – such as an overhanging or dangerous trees! Instead the latter would be dealt with in civil courts.

§5.42 – Tree Preservation Order

Under the Town and Country Planning (Trees) Regulations 1999 the purpose of a Tree Preservation Order (TPO) is to protect trees that have a particularly high amenity value. Reasons for this may include historical significance, biological importance, extreme beauty or value, unusual properties or traits (i.e. if it is a unique hybrid), amongst other similar reasons. In a broad sense if a tree is in any way important or significant then it is likely to have a TPO placed upon it by local councils.

A TPO's purpose is to prevent damage to the tree by placed severe punishments upon whomever commits such acts. Via the Town and Country Planning (Trees) Regulations TPOs prohibit individuals from cutting down, loping, topping, uprooting, damaging or destroying the protected tree, or by allowing or aiding such to occur by another's hand.

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[118] Prescription Act 1832, Gov.uk, http://www.legislation.gov.uk/ukpga/Will4/2-3/71/section/3

[119] "Right to Light", RICS, http://www.rics.org/uk/knowledge/consumer-guides/rights-to-light/

An example of a TPO near to where I live concerns ten 38 year old Norway Maples outside the local district hospital[120]. The hospital trust itself strongly opposes such, stating that they are "average", "in decline" and "unworthy of protection", but there is a widely held belief that they have become part of the fabric of the local area – and are thus protected. Another purpose of this TPO, and of many other TPOs nationwide, is to prevent the unnecessary risk involved in replacing the trees with a different species. For example, in the above example there is a desire from the hospital trust to replace the Norway Maples with easier to maintain Birches. However, the council decided, on the advice of an arborist, that the risk involved in removing well established mature trees and replacing them with difficult to manage root-balled semi-mature trees that are unlikely to be given the care they require to survive, would be an unreasonable risk.

[120] "The SSDC (Yeovil No. 1) Tree Preservation Order 2011", Area South Committee, https://www.southsomerset.gov.uk/media/331498/8._the_ssdc_yeovil_no.1_tree_preservation_order_2011.pdf

Learner Name	Marley Sexton
Qualification Title	ABC Level 2 Certificate in Arboriculture
QAN	
Location of Task	Mendip District Council
Date	6 Mar, 2017
Witness Name	Bo Walsh
Relationship to Learner	None/Council Tree Officer
Contact Detail	01749 341434, bo.walsh@mendip.gov.uk

Unit(s) / LO(s) / AC(s)	Description of activity undertaken
Unit 5, LO 4, AC 5	Emailed a nearby council to gather information concerning TPOs and the required information that is needed to submit an application for work.

Witness Statement
"*Dear Mr Sexton, (…)* *TPO trees are subject to the regulations defined in The Town and Country Planning (Tree Preservation)(England) Regulations 2012 - http://www.legislation.gov.uk/uksi/2012/605/made. These regulations came about as a result of the Town and Country Planning Act 1990 (primary legislation).* *TPO tree works applications are effectively the same as full planning applications – so the level of information provided is important. This information does depend on the reason(s) for the proposed works – e.g. To crown thin a tree to allow more light into a garden is different from proposing to fell a tree because it is alleged to be causing subsidence to a building or to reduce the length of a primary limb because it has a structural weakness or to crown lift a tree because it has low branches over a highway.* *The level of information needs to have sufficient detail to be able to support the specified work – NB. please refer to the tree works application form and guidance notes for more information / guidance.* *Although many house-holders / residents are happy to apply for works to TPO trees – it is usually more appropriate for them to seek the advice / guidance of a suitably qualified / experienced arborist or consultant before making an application.* *This is because an arboriculturalist should be more able to understand the principles of arboriculture / bio-mechanics / structural integrity / pest / disease / ecology, etc of the tree and is environment and be able to prescribe remedial works when necessary and, perhaps more importantly, be able to advise why "no works" are necessary for example good husbandry may simply involve keeping an eye on the tree at regular intervals."*

We confirm that the above is an accurate record of the activity.

Learner Signature	*Marley Sexton*	Date	06/01/2017
Witness Signature	*Bo Walsh*, via Email	Date	06/01/2017

I confirm / do not confirm (Delete as appropriate) achievement of the assessment activity

Action Required			
Assessor Signature		Date	
Internal Moderator/Quality Assurer signature (if sampled)		Date	

For the owner of a tree protected by a TPO there are numerous implications. The most obvious is that work cannot be carried out upon it without the council's permission and written consent from the local planning authority (LPA) – except in serious extenuating circumstances, such as an immediate risk to the health and safety of others or the risk of damage to property. Examples of when this might apply include dislodged or snapped branches after storms, or the presence of severe rot in a major arterial branch[121]. Written requests for permission must be placed at least 8 weeks before work is due to begin.

Besides this the owner may also have to replant any destroyed or dead trees, as per the order. Even where permission is granted to fell a TPO tree there may be a requirement to replant, as well.

Another, perhaps slightly more positive implication, is that the landowner has the possibility of claiming compensation for a number of different consequences of TPOs: the first is to acquire the funds necessary to protect the tree from harm, and the second concerns payment to cover the cost of any financial losses as a result of the TPO. For example, if a TPO is placed on a tree on a potential development site, then the owner could, in theory, claim compensation if the value of the land has decreased due to the reduction in the desirability for it to be developed. Another example is if a forest that is being cleared to make way for farmland has a TPO placed on one of the trees, then it could be argued that the value of the farmland may have had decreased with a protected tree stuck in the middle of it!

In terms of the penalties for breaching TPOs the maximum possible fine for felling is stated as unlimited if taken to a Crown Court (in cases where exceptionally valuable or precious trees have been felled) or up to twice the value of the tree, or £20,000 – whichever is lowest – for cases tried at magistrates. For damaging, topping or lopping a tree, without consent, the maximum fine is £2,500 plus the value of any financial gain acquired from such acts.

There is a long and detailed process which must be undertaken to be approved to perform work upon, or fell, a TPO tree. As we can see on the flowchart on the opposite page (Figure 108: TPO Permission Flowchart), obtained from the Government website.

In essence the system goes as follows. For non-emergency work, an enquiry must be made to the LPA, who will then come out and inspect the site and provide pre-application advice. This is likely the stage where one might first get a "gist" of whether such work would be approved.

If one is happy with the visit, then a formal application can be submitted to the LPA. This form will require such details as the location and condition of the tree, the extent of the work wishing to be carried out, who wishes to carry out the work, and so on. The LPA then has a duty to respond to this application within 8 weeks. The process may include a second site visit and discussion with the landowner.

If the LPA decides to approve the application, they may impose certain conditions on the work. For example, if a TPO tree is to be felled, then they may require that it is replanted subsequently. In both this situation, and if the work request is denied, then the owner has the right to appeal to the Secretary of State within 28 days.

To appeal one must fill out an appeal form[122], and consent to a site visit. After this there can be a wait of up to 27 weeks before a decision is made. If the application is rejected once again, then the last step would be to escalate it to the High Court[123], at which point the advice of a lawyer should be sought. An

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[121] "Protected Trees", HM Government, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/244528/2127793.pdf

[122] "TPO Appeal Form", HM Government, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/500965/TPO_appeal_form_Feb_2016.pdf

[123] "Appeal a decision about a tree preservation order", Gov.uk, https://www.gov.uk/appeal-decision-about-tree-order/if-you-disagree-with-the-appeal-decision

example of this happening was in Surry, where four Oak trees were ring-barked[124]. The workers took the local council to the High Court after proceedings to prosecute them were undertaken. They successfully won, and the council had to pay costs, since the TPO had not been served properly.

Given all this one might rightfully assume that carrying out work on a TPO protected tree is strictly prohibited in all circumstances, but this is not necessarily the case. Four scenarios where work can proceed on a TPO protected tree without permission are[125]:

1. *Health and Safety Grounds.* If there is an immediate and pressing risk to the health and safety on individuals, or to property, then emergency work can be undertaken to shore up the tree and prevent a disaster occurring. And example of this is damage caused by a storm which might result in a large branch falling to the ground. In this scenario emergency work can be undertaken without permission to ensure the tree is safe.
2. *Fruit tree pruning*. Any fruit trees that require pruning for business reasons can be pruned without permission from the LPA, even if they have TPO placed upon them.
3. *Dead trees*. Any trees which are *objectively* dead can be removed without permission. It is worth noting that the owner would need to be able to prove the tree is dead should they be taken to court.
4. *Act of Parliament*. Any work that needs to be carried out due to an Act of Parliament can proceed even if it require the removing or modification of a TPO Protected tree.

[124] "Four trees cost council £100,000 in the High Court", Surry Mirror, http://www.surreymirror.co.uk/trees-cost-council-pound-100-000-high-court/story-20768311-detail/story.html

[125] "TPO", NatureNet, http://naturenet.net/trees/tpo.htm

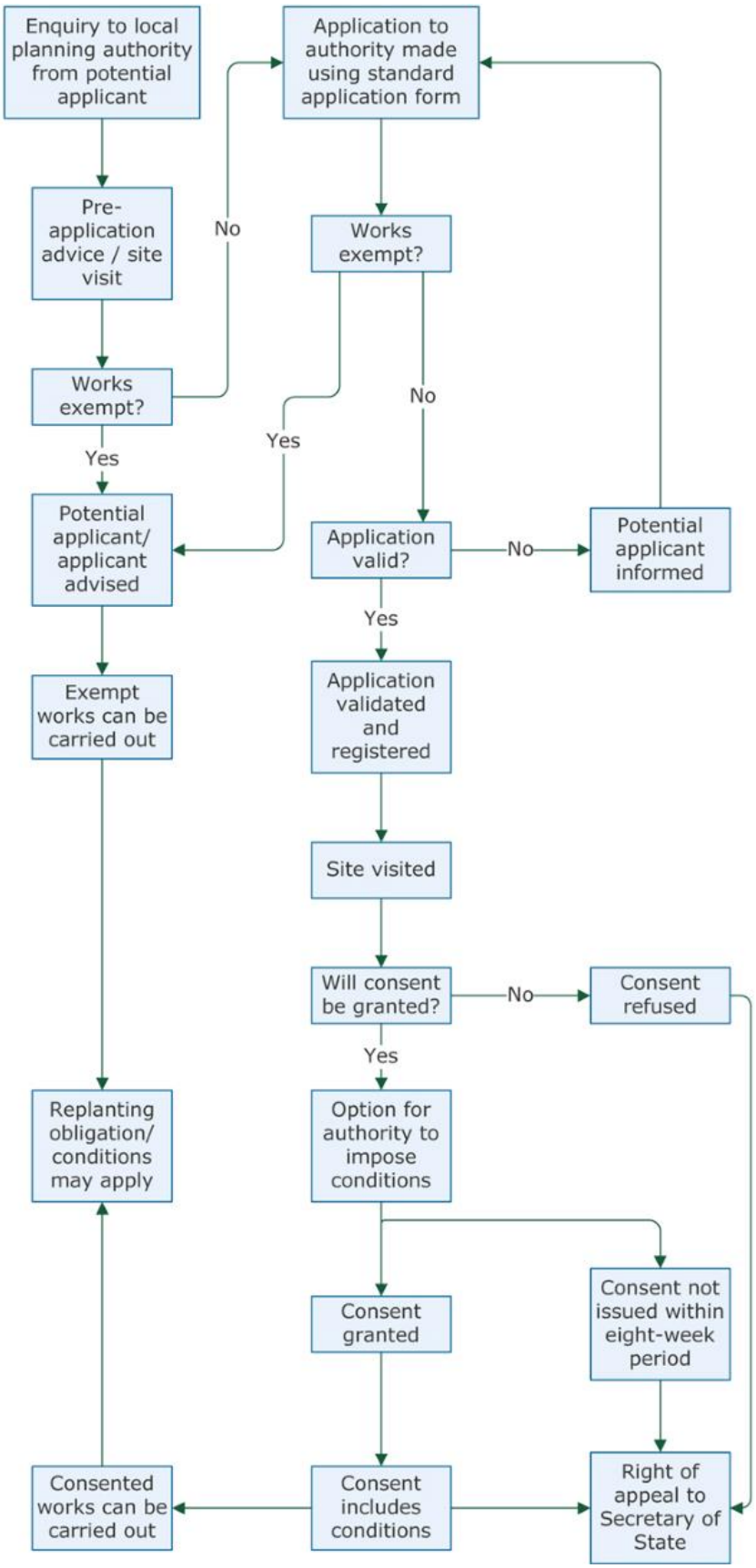


Figure 108: TPO Permission Flowchart, via Gov.uk

§5.43 – Conservation Areas

Conservation areas, Sites of Special Scientific Interest (SSSI) or Area of Outstanding Natural Beauty (AONB), amongst other designations, set out the protections granted to large areas of land that have a special interest owing to it's unique, rare, unusual or beautiful flora or fauna, or cultural or scenic value. The purpose of the designation, then, is to ensure that such areas are preserved for the future and that they are not destroyed without good reason.

An example of this is the Blackdown Hills in Devon and Somerset (Figure 109: A forest within the Blackdown Hills). This area is designated as a AONB, with smaller parts contained therein labelled as SSSIs. For this reason, large areas require planning permission to undertake any work, and there are strict laws in place for those who damage or destroy the natural habitats of trees, plants or animals. The primary stated purpose for the designation, according to the local council, is threefold: firstly, to promote and protect its visual aesthetic; secondly, to promote sustainable for of economic development; and lastly to ensure that all activities are well communicated and planned and go towards the education and development of future protectors[126].



Figure 109: A forest within the Blackdown Hills

Regardless, when it comes to trees themselves, the implications for the owner of such is that they would require a felling license from the forestry commission to undertake work. Indeed, in all conservation areas, and any woodland areas in general, a felling license would be required before work is undertaken

[126] "Blackdown Hills Management Plan", Taunton and Dead Council https://www.tauntondeane.gov.uk/irj/go/km/docs/CouncilDocuments/TDBC/Documents/Forward%20Planning/Evidence%20Base/BHAONB%20Management%20Plan.pdf

– granted that the trees are not exempt from such. For the owner of such land upon which trees grow the implications are obvious: the need to apply for and be granted a felling license from the Forestry Commission. Furthermore, if the tree or trees to be felled are included in a SSSI, AONB or are protected by a TPO then further advice and permission must be sought from the local council and LPA, again only if exemptions do not apply. The penalties for contravening any of these aspects is the same as that for contravening a TPO.

The process that one must go through to work within a conservation area is very similar to that of which concerns TPOs, as we can see in Figure 110: Flowchart concerning application for work in a conservation area.

In essence a section 211 notice must be issued, of which the council then have 6 weeks within which to respond. A site visit may be undertaken (and the owner will be notified if the trees are exempt) before a public consultation go ahead. If there are any objections to the work, then the LPA will consider whether a TPO would be appropriate for the tree or trees. If not, then the work can go ahead within 2 years. If so, then the work will not be allowed to proceed and the owner must go through the TPO application process as mentioned previously. If the 6-week deadline expires, or if the trees are exempt, then the work can go ahead but there may be a requirement to replant afterwards.

As mentioned, there exist exemptions to the above, which would allow work within a conservation area to proceed without permission from the LPA. Some of these include:

1. Emergency works. Any work which is needed to prevent damage to property, or to reduce the risk to the public, can be undertaken without going through the long process of applying for permission.
2. Highways. Any orders from the Secretary of State for Transport to build or develop highways through conservations areas can go ahead without permission.
3. National Security. Any police or military forces can undertake work on trees within conservation areas without permission if it is in the interests of national security.
4. If the tree within the conservation area has a TPO placed upon it, and permission has been granted through TPO channels to work on the tree, then no permission from the council is required. i.e. if the LPA has approved work then the council themselves need not to approve the work too.

Furthermore, there are means by which an individual is exempt from a felling license, which include:

1. If the trees diameter at breast height (1.5m) is less then 75mm and not coppiced, 150mm and coppiced, or 100mm with the desired felling to be performed to thin out forest to promote the growth of other trees[127]
2. If there is permission from the Forestry Commission, and it is in their interests that work can go ahead.
3. Hedge Management. If the work is undertaken to manage a hedge row, regardless of whether there are tree's present therein, then there is no need for a felling license.
4. Obstructions to utilities. This may include electricity lines or sewage pipes. If tree's are damaging, or may damage or obstruct such, then felling can proceed without a license. This is particularly beneficial to those who work for power companies managing the power line as it ensures that emergency work, or otherwise, can proceed quickly and efficiently where required.

The full range of exemptions to felling licenses are shown in Figure 111: Felling Licence Flowchart.

An example of when a felling license is and is not required concerns the location of my felling course in the Blackdown Hills. The spruces were tall but not particularly wide, and therefore since they did not

[127] "Exceptions relating to section 211 notices", Gov.uk, https://www.gov.uk/guidance/tree-preservation-orders-and-trees-in-conservation-areas#section-211-notice-for-tree-size

each contain more than 5 tonnes of wood[128] a felling license was not required for work, and training, to go ahead.

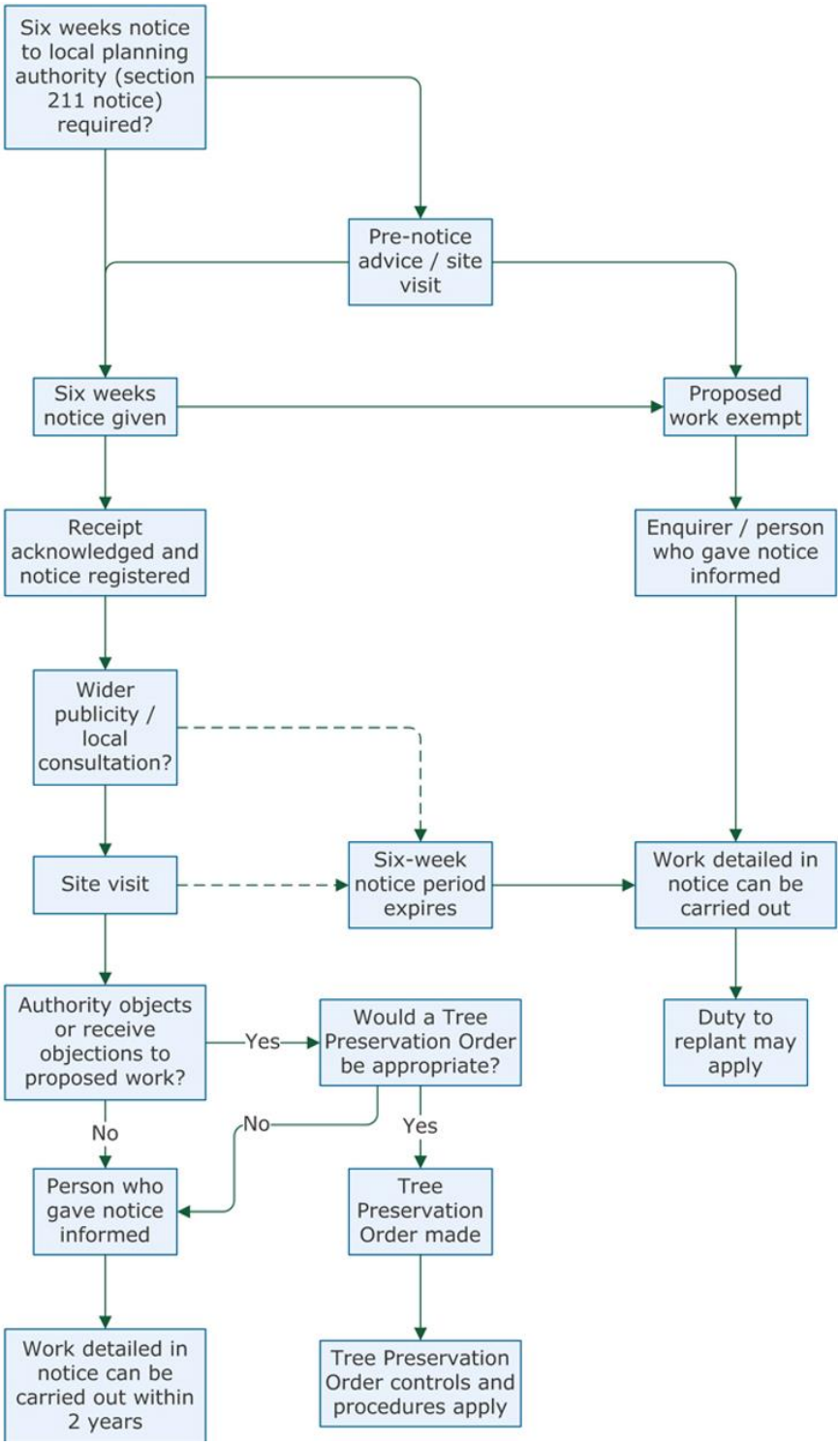


Figure 110: Flowchart concerning application for work in a conservation area, via Gov.uk

[128] "Do I need a felling license", Experts123, http://www.experts123.com/q/do-i-need-a-forestry-commission-felling-licence-to-cut-down-trees-covered-by-a-tree-preservation-order.html

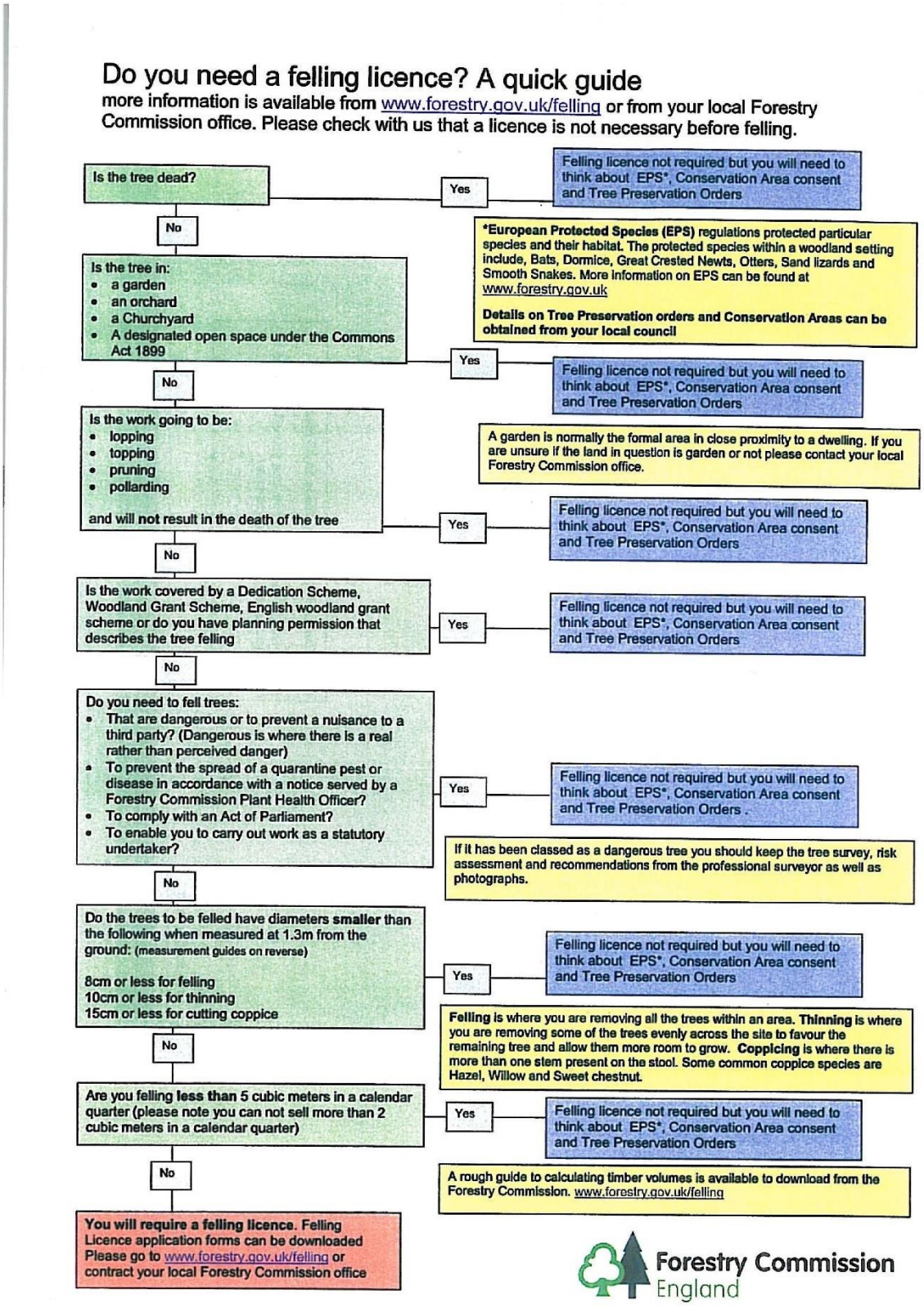


Figure 111: Felling Licence Flowchart

§5.44 – Working on Protected Trees, the Information Required

The information required to work on a protected tree, especially one protected by a TPO, varies slightly council by council – but it is helpful nonetheless to examine an application form to see exactly what information *is* required (I have provided this in the next four pages overleaf).

In essence all the usual information is required, and it bears some similarity to the information required in a LPA planning application. The name, address and contact details of both the applicant and any agents working for them, is required, followed by the location of the trees and the owner thereof.

Next a detailed explanation of the work that is desired to be carried out, the purpose of such, and any additional information needs to be put down in writing. If the tree-works are required due to ill health or sustenance issues, then there is a requirement for an expert witness – a tree surveyor – to provide their own written report alongside.

A declaration then needs to be signed which enters the applicant into a legal agreement that says, simply, that what they have written is to the best of their knowledge correct.

As with all applications it is always worthwhile to investigate whether an authority is required to approve work – whether that be the LPA or Forestry Commission – or whether the work is exempt from the regulations.

An actual example of this concerns the trees found at Saltram House in Plymouth. This site is owned by the National Trust but the trees fall under the protection of the Forestry Commission. I contacted them to determine whether a felling license is required to undertake work on the trees at that location and they proclaimed that all the usual exemptions apply. Thus, if less then $5m^3$ of timber is to be felled in a year then no license is required, but if more then this needs to be removed then a licence would certainly be required.

Customer Services
Cannards Grave Road, Shepton Mallet, Somerset, BA4 5BT
Telephone 01749 648999 Fax 01749 344050
Email: customerservices@mendip.gov.uk
Minicom: 01749 341622 www.mendip.gov.uk

Application for tree works: works to trees subject to a preservation order (TPO) and/or notification of proposed works to trees in conservation areas (CA).

Town and Country Planning Act 1990

Publication of planning applications on council websites

Please note that with the exception of applicant contact details and Certificates of Ownership, the information provided on this application form and in supporting documents may be published on the council's website.

If you have provided any other information as part of your application which falls within the definition of personal data under the Data Protection Act which you do not wish to be published on the council's website, please contact the council's planning department.

Please complete using block capitals and black ink.
It is important that you read the accompanying guidance notes as incorrect completion will delay the processing of your application.

1. Applicant Name and Address		2. Agent Name and Address	
Title:		Title:	
First name:		First name:	
Last name:		Last name:	
Company (optional):		Company (optional):	
Unit:		Unit:	
House number:		House number:	
House suffix:		House suffix:	
House name:		House name:	
Address 1:		Address 1:	
Address 2:		Address 2:	
Address 3:		Address 3:	
Town:		Town:	
County:		County:	
Country:		Country:	
Postcode:		Postcode:	

$Date: 2008/05/16 11:20:03 $ $Revision: 1.25 $

3. Trees Location

Full address/location of the site where the tree(s) stand (including full postcode where available)

Unit: | House number: | House suffix:

House name:

Address 1:

Address 2:

Address 3:

Town:

County:

Postcode (if known):

If there is not a full postal address, describe as clearly as possible where it is (for example, 'Land to the rear of 12 to 18 High Street' or 'Woodland adjoining Main Road') or provide a grid reference:

Easting:

Northing:

Description:

4. Trees Ownership

Is the applicant the owner of the tree(s): ☐ Yes ☐ No

If 'No' please provide the address of the owner (if known and if different from the trees location)

Title: | First name:

Last name:

Company (optional):

Unit: | House number: | House suffix:

House name:

Address 1:

Address 2:

Address 3:

Town:

County:

Country:

Postcode:

Telephone numbers

Country code: | National number: | Extension number:

Country code: | Mobile number (optional):

Country code: | Fax number (optional):

Email address (optional):

5. What Are You Applying For?

Are you wishing to carry out works to tree(s) in a Conservation Area (CA)? ☐ Yes ☐ No

Are you seeking consent for works to tree(s) Subject to a Tree Preservation Order (TPO)? ☐ Yes ☐ No

6. Tree Preservation Order Details

Do you know the title of the Tree Preservation Order (TPO)? ☐ Yes ☐ No

If Yes, please provide the title of the TPO:

7. Identification Of Tree(s) And Description Of Works

Please identify the tree(s) and provide a full and clear specification of the works you want to carry out. Enter the species of the tree(s) and include a sketch plan showing position(s) of the tree(s) in relation to buildings, named roads and boundaries.

If the trees are protected by a TPO, if possible please number them as shown in the First Schedule to the Tree Preservation Order (for example T3 Oak; two Beech and one Birch in G2; seven Ash in A1; sycamore in W1).

Trees and proposed works:

You might find it helpful to consult a tree surgeon to clarify what needs to be done.

Please state the reference number you have given the plan:

$Date:2008/05/16 11:20:03 $ $Revision: 1.25 $

8. Trees - Reasons For Works

This section only needs to be completed if you are seeking consent to trees under a Tree Preservation Order (TPO)

Please state the reasons for carrying out the proposed works on the tree(s):

Please indicate whether the reasons for carrying out the proposed works include any of the following. If so, your application must be accompanied by the documents specified.

Health or safety of the tree(s) - e.g. it is diseased, fears that it might break or fall: ☐ Yes ☐ No

If Yes, information required - report by a tree professional (e.g. arboriculturist, horticultural adviser).

Alleged subsidence damage: ☐ Yes ☐ No

If Yes, Information required: Full report by an engineer or surveyor, together with one from a tree professional - to include date and description of property damage; sub-soil type and shrinkage potential; location of any roots found and their identification; history of ground and building movement through a distortion survey and/or level or crack monitoring over suitable period; other vegetation in the vicinity and its management since discovery of the damage.

9. Trees - Additional Information

Are you providing additional information in support of your application? ☐ Yes ☐ No

If Yes, please provide the reference numbers of plans, documents, professional reports etc in support of your application:

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10. Application For Tree Works - Checklist

Please use this checklist to ensure that the form has been completed correctly and that all relevant information is submitted.

For works to trees protected by a Tree Preservation Order, failure to supply sufficiently precise and detailed information may result in your application being rejected or delay in dealing with it. In particular, you MUST provide the following:

The original and 3 copies of a completed and dated application form. ☐

The original and 3 copies of a sketch plan showing the location of all tree(s). ☐

The original and 3 copies of a full and clear specification of the works to be carried out. ☐

The original and 3 copies of a statement of reasons for the proposed work. ☐

- evidence in support of statement of reasons. In particular, you should provide:

  The original and 3 copies of a report by a tree professional (e.g. arboriculturist or horticultural adviser) if your reasons relate to the health and/or safety of the tree(s). ☐

  The original and 3 copies of a report by an engineer or surveyor, together with one from a tree professional (arboriculturist) if you are alleging subsidence damage. ☐

For works to trees in conservation areas, it is important to supply precise and detailed information on your proposal. You may, therefore, wish to provide the following:

The original and 3 copies of a completed and dated form, with all questions answered. ☐

The original and 3 copies of a sketch plan showing the precise location of all tree(s). ☐

The original and 3 copies of a full and clear specification of the works to be carried out. ☐

Whether the trees are protected by a TPO or in a conservation area, please indicate which of the following types of additional information you are submitting (the original and 3 copies of each need to be provided):

- photographs. ☐

- report by a tree professional (arboriculturist) or other. ☐

- details of any assistance or advice sought from a Local Planning Authority officer prior to submitting this form. ☐

11. Declaration - Trees

I/we hereby apply for consent/give notice as described in this form and the accompanying plans and additional information.

Signed - Applicant:

Or signed - Agent:

Date (DD/MM/YYYY):

(date cannot be pre-application)

12. Applicant Contact Details

Telephone numbers

Country code: | National number: | Extension number:

Country code: | Mobile number (optional):

Country code: | Fax number (optional):

Email address (optional):

13. Agent Contact Details

Telephone numbers

Country code: | National number: | Extension number:

Country code: | Mobile number (optional):

Country code: | Fax number (optional):

Email address (optional):

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https://ecab.planningportal.co.uk/uploads/1app/guidance/guidance_note-works_to_trees.pdf